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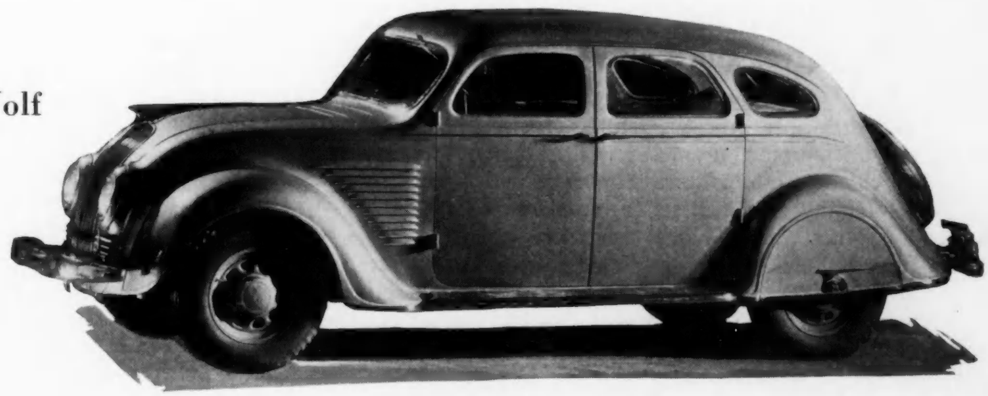
1934 Marks Turn from Conventional in Automobile Design

By Austin M. Wolf



De Soto "Airflow" sedan

AUTOMOBILE design has become imbued with the "new deal" and this year will go down in history as the turning point from the conventional. Traditions have been scrapped and better performance, economy and beauty have resulted. The ability of small cars to attain speeds of 80 m.p.h. or better is indicative of the formidable improvements made in this class.

Streamlining has come into its own in a bold manner as compared with the trivial and reticent efforts of the past. Individual wheel suspension at the front is taking a prominent place among the new developments. In the commercial and bus fields, unconventional powerplants together with the modification of their usual location indicates a similar desire to remove this phase from the orthodox.

Other prominent features in the new models are engine supercharging, increase of aluminum heads, aluminum piston treatment, voltage regulation and lamp load control generators for passenger cars, direct-acting shock-absorbers, flanged fixed-focus head-lamp bulbs, magnetically-controlled beam tilting, flatter tire profiles and body ventilating systems. In the heavy duty field camel-back trucks, rear powerplants, Diesel and horizontal engines are notable examples of a new perspective.

Texas Co. tank truck with rear powerplant

Developments in Powerplants

Compression ratios have been slightly increased and particularly so where aluminum heads have been adopted as in the case of the Studebaker Dictator and Commander, De Soto, Plymouth (special), Auburn-6 and Custom-8, Chrysler Imperial and Lincoln. In the latter the combustion chambers are polished, the ratio being raised from 5.5 to 6.1-1. Studebaker runs 6.3-1. Hudson and Terraplane provide a composite aluminum and iron head on the De Luxe series with 6.25-1 compression ratio. The Standard series has a cast iron head at 5.75-1. A "super power" head, also of the composite type and obtainable at extra cost, has a 7-1 ratio. One horsepower per 24 lb. of car weight is obtained in the Hudson roadster with the "super power" head. The Auburn Custom-8 with an aluminum head with 14 mm. plugs develops 115 hp. at 3600 r.p.m. The Standard-8 with a cast iron head using 18 mm. plugs develops 100 hp. at 3400 r.p.m. All Cadillac engines have a 6.25-1 ratio, made possible by a new combustion chamber shape, aluminum pistons and a cold air intake. The Chevrolet combustion chamber pocket has been eliminated and a sloping roof is provided for the exhaust valve seat with the spark-plug in close proximity. More surface is thus provided over the area where ignition

initiates. The intake valve is in the area of the last gas burned and remains in the flat roof. It is given a slight tilt for better cylinder filling. There have been numerous cases in which the bores have been slightly increased in order to attain more power. The use of chrome alloy cast iron is more common for cylinder blocks. Hudson is using a new cylinder head gasket of the sealed type with asbestos filler, using steel which does not oxidize as is the case with copper. Rods passing through the cylinder heads, cylinder block, crankcase and main bearing caps in the Hercules Diesel are provided with eccentric heads located in a recess in the top of the crankcase to prevent them from turning when the nuts on either end are tightened up.

Valves and Valve Gear

The exhaust valve insert finds new adherents in Ford, Lincoln and Brockway, who use a tungsten steel alloy. The Thompson "durachrome" insert is found in the entire Chrysler line, Lycoming, International Harvester and Waukesha. The greater ability of the insert to retain the valve seal in spite of a slightly warped block top-surface is being recognized. There is a tendency in present engines toward a wider seat to provide better cooling. The Doman and Marks air-cooled engine utilizes Ni-Resist valve seats and guides and bronze spark-plug bushings in the aluminum head and the hydraulic type valve clearance compensator, introduced on, and continued by, Pierce-Arrow. It is now redesigned with the plunger spring at the top and the ball check valve slightly above the center of the assembly. It takes up clearance under all conditions and makes for quieter operation.

In the Ford-8 each valve, spring, retainer and the split-valve guide form a unit that can be inserted through or removed from the valve port, saving time and making tappet clearance an easy operation. It is held in place by a yoke clip fitting into a groove of the guide.

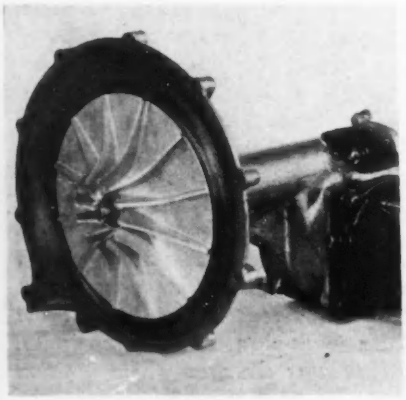
There is a trend toward a tongue and groove spring retainer lock on valve stems. At higher speeds it has been found essential to have a snug fit of all parts of the retainer mechanism to overcome breakage formerly experienced. The Thompson unit is being used by Chrysler, Oldsmobile, International Harvester and Waukesha. Studebaker continues the cup with opposed extending fingers as a spring surge damper, located at the top of the spring. Hudson and Terraplane invert the cup and locate it above the spring retainer. On the Studebaker Dictator the damper is produced of flat stock and formed in a spiral of opposite hand to the spring and is threaded down over the tapered valve spring from the top. Hudson and Terraplane valve springs are pre-set and rust-proofed. The Auburn springs are compressed and the ends faced square to prevent their taking an angular position in operation.

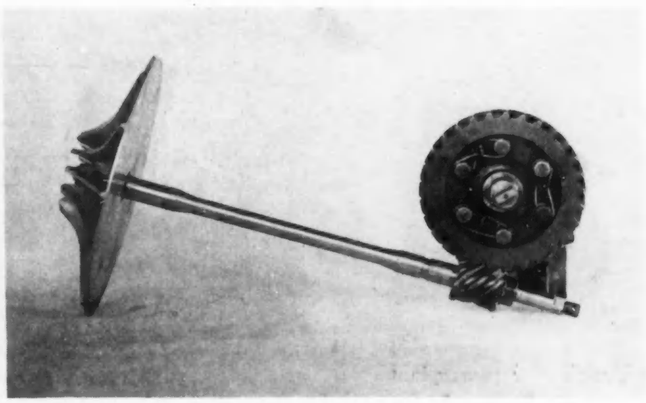
Copper plating on the valve lifter rollers and pins of the Buick engine prevents scoring during the breaking-in period. The rectangular base of the Hudson and Terraplane tappet is formed with a 1½ in. radius in a transverse plane. The guide prevents rotation of the tappet by contacting with the transverse end surfaces of the base. Dodge uses the "Proferal" cast-iron camshaft, as do Hudson and Terraplane. The Packard-8 camshaft is carried in steel-backed babbitt-lined bearings. Cam contours are of non-symmetrical shape to eliminate valve chatter. Buick provides a double-walled timing gear case for noise insulation. The engine wall is machined smooth, thus preventing any current of air from striking the gear teeth and causing a whine or whistle. Auburn uses a non-adjustable chain due to the short center between cam and crankshafts. Lafayette has chain drive.

Piston and Connecting Rod

The aluminum piston has gained ground and is now used by Studebaker, Cadillac and Lincoln; all have adopted the Lo-Ex T-slot type. Of particular interest is the Alumilite coating. Pistons are oxidized by immersing, after complete machining, in a solution of sulphuric and oxalic acids and water at a temperature of 85 deg. for 40 min., through a reverse electroplating process giving a coating of 0.0005 in. depth. It is claimed that oil penetrates and adheres with greater volume to an oxidized piston than to a plain aluminum or cast-iron one. The coating hardness eliminates scuffing and reduces wear both on the skirt and in the ring grooves. Buick and Oldsmobile continue with the electroplated cast-iron piston which has also been adopted in the new White models 701 and 702.

The Perfect Circle "70" compression ring has a small groove in the outer lower corner which is stopped off on each side of the joint giving a full ring face at this point. Oil is thus held in the groove and provides a better seal for reduced blow-by and decreased oil consumption. The Wilkening "DV" oil control ring has a groove of square section, a diagonal of which is vertical and slightly behind the front ring face. The undercut thus formed provides an angular scraping face on each side of the groove which is larger than usual to allow for the momentary storage of a greater volume of oil. As the ring face wears the area of contact with the cylinder wall is reduced, compensating for the loss of tension due to wear.





Graham supercharger driven off rear end of water pump shaft

An aluminum piston skirt expander has been developed for the service field consisting of a piece of spring steel wire formed in a series of waves and introduced into each piston slot previously grooved at each side by a special milling cutter. In the development of this device it was found that in most cases piston slap does not result from excessive clearance in the cylinder but from the momentary collapse of the piston under the force of the explosion.

The Studebaker Commander and President use ventilated inner rings back of the type "85" Perfect Circle oil control rings. Packard is using one straight compression ring at the top, two "70" and an "85" below. Hudson and Terraplane pin the rings and claim to improve the sealing ability by preventing rotation in the piston.

Pierce-Arrow is providing double-drilled connecting rods to supply oil to the low as well as the high pressure sides of the pistons to eliminate scuffing. Lafayette has a combination of rifle-drilled steel rods and aluminum invar-strut pistons. The Plymouth connecting rod cap is provided with reinforcing ribs for strength and heat radiation.

Crankshaft and Crankcase Practice

The "cast-iron" crankshaft is now in production on the Ford-8. It consists of high carbon alloy steel with high copper chrome-silicon content providing a hard surface and self-lubricating effect due to the high graphitic content. Through the coring of the crankpins and slight reduction in the counterbalances, the new shaft weighs 10 lb. less than the forged one. The cast crankshaft is opening up possibilities for unconventional crankpin arrangements which could not ordinarily be forged. The Terraplane crankshaft is now provided with eight integral counterweights in place of the four bolted-on type previously used. A new crankshaft in the larger Pierce-Arrow-8 has 16 integral forged-on counterweights. The leaded-bronze steel-backed main bearing is used by Studebaker and Lincoln, the latter also using it for the connecting rod. In the Ford truck, the floating connecting rod bearing is of this type.

The Studebaker Dictator has a vibration damper flywheel disc mounted over two rubber rings each of which is provided with six buttons that project into holes in the damper flywheel. In the Commander and President the damper is mounted on four rubber cones which are held in place between the fan pulley and the damper flange by spacer tubes and cap screws which pass through the center of the rubber cushions.

Lubrication

A 100 per cent oil filter, Purolator L type, is used by Packard and Pierce-Arrow. A knife cleaning arrangement for accumulated film has been added to some of the Purolator models with the metal element. Cuno have developed a Nofabrix filter utilizing molten lime rock in a fibrous state. Their Lifetime filter is used on the Cadillac-12 and 16, Cunningham, Reo 4-ton truck and the Wright and Pratt and Whitney aircraft engines.

The Viscon oil temperature regulator is used by Buick, Pierce-Arrow, Packard, Lincoln, Mack 6-cylinder, Lycoming and Hupmobile 8-cylinder engines, Reo, Waukesha and General Motors truck engines and the Brockway valve-in-head engines.

Packard, Hudson and Terraplane have increased the capacity of their oil pumps and lines. The Pontiac pump circulates oil at the rate of 225 gal. per hr. at a road speed of 60 m.p.h. Hudson, Terraplane and Chevrolet continue with the splash system. Ford has obtained greater oil economy through the use of new piston rings, modifications in the piston including reduction of the oil drain holes from twelve to eight, the installation of baffle plates over the oil return holes in the valve chamber and by a redesigned oil pan tray permitting quicker return of oil to the sump. The crankcase breather and oil filler are combined in the Doman and Marks engine in such a way that the oil supply can be replenished from either side. A ball check valve is provided in the oil return hole in the cap of the rear main bearing to prevent leakage on steep grades. Auburn uses the Floto pump inlet on all models.

IN this article Mr. Wolf analyzes the mechanical developments revealed in the 1934 cars under the following headings:

Developments in Powerplants
Valves and Valve Gear
Piston and Connecting Rod
Crankshaft and Crankcase Practice
Lubrication
Cooling System
Fuel and Exhaust Systems
Electrical System
Engine Mounting
Clutch
Transmission
Universal Joints
Axles and Braking System
Wheels and Tires
Suspension
Frame
Control
Equipment
Sheet Metal and Bodies
Ventilation
Doors, Windows, and Fittings
Seats, Upholstery, and Luggage Space

Cooling System

Radiator fronts are more rounded than formerly. In some instances the top of the shell projects forward ahead of the grille. Most grilles have a chromium finish but Nash is using aluminum with an Alumilite finish, and Auburn a similar anodic finish framed in a chromium beading. Whereas Ford has straightened the grille front and eliminated the previous forward curve at the bottom, Oldsmobile is curving the lower portion to make it conform with the contour of the front fenders and radiator shell. Both the Oldsmobile and Buick grille slope outwardly at a decided angle from top to bottom. Auburn has two pentagonal grilles at the bottom acting as air scoops to hold down the under-hood temperature. Buick and Plymouth now place the filler cap under the hood. The Buick V-type radiator is fitted with a chromium finished grille and there is a colored center strip in the

shell from top to bottom. Most radiator shells are finished in the same color as the hood to accentuate length.

Lincoln and Terraplane have increased their cooling efficiencies 15 and 20 per cent respectively. The Pontiac water jacket capacity has been increased, the fan elevated to the center of the radiator core and the pump flow is 1200 gal. per min. at a road speed of 25 m.p.h. Hudson has increased its pump capacity and together with Terraplane provide a water level indicator in place of the temperature indicator on the instrument panel. A cork float in the radiator top tank makes a contact to actuate the instrument hand. Thermostats are now used on Hudson, Terraplane, Plymouth and Ford.

Water entering the Chevrolet head is directed toward the exhaust valve seats to give them the benefit of the coolest water. The Auburn pump feeds directly into a copper tube running the length of the block and which supplies an even stream of water to the valve seats. The pump is provided with metallic packings, eliminating the stuffing box. The hardened steel impeller-fan shaft runs in two ball bearings. The De Soto radiator is concealed by a flush front-end grille with an open-work, pointed ornament at the top. In the Chrysler the grille consists of chromium bars set above the front nose surface with an ornament at the top consisting of a new version of the Chrysler wings in V formation. In both of these cars the supply tank is mounted on the panel beside the engine. With the low core position the fan is placed directly on the front end of the crankshaft. The water pump and generator are now the only units driven by belt. A crankshaft fan is similarly used on two new Hercules 4-cylinder engines of 58.8 and 64.9 cu. in. displacement when used as industrial units in which the base also acts as an oil pan. The radiator extends the full height of the engine, being bolted directly to the cylinder head and the base.

The Hall-Scott horizontal engine provides the water pump with a special lubrication and water seal. A soft grease compartment is provided on the pump side with a rotary seal at the end of the bushing. On the drive sprocket side, two rawhide seals are used back to back with a drain ventilated space between them. Cuno has developed a radiator control valve on the over-flow line, providing closed radiation and permitting 3 or 4 lb. pressure on the cooling system, slightly raising the boiling point and preventing loss out of the overflow pipe. It also acts as a warning signal by whistling when steam passes through it.

In the Doman and Marks air-cooled engines the cooling fins are ½ in. shorter on the blast side in order to equalize cylinder temperatures. Cooling air from the centrifugal blower is divided into two streams, one directed against the cylinder heads and the other against the cylinders, thereby preventing eddying.

Fuel and Exhaust Systems

Carburetor air is collected on the Cadillac from the space between the radiator core and casing and led through flexible tubing to the air cleaner and silencer, resulting in a decrease of about 100 deg. fahr. The cooler intake temperature has made a greater spark advance possible. Intake silencers are now used on every car. Most of them are combinations of tuned resonance chambers to remove the low frequencies and a limited amount of absorbing material to remove hissing and sucking noises. More attention is being paid this year to two or more tuned resonance chambers which handle a variety of peaks in the lower frequency ranges. AC has developed an oil washing air cleaner with practically 100 per cent efficiency and of reasonable size for passenger car service in dusty territories. Burgess is producing a viscous coated type using cellulose fibre which can be serviced by immersing in gasoline and re-oiled in the ordinary way. This unit is standard equipment on Studebaker. For heavy duty work, the Handy oil-wash type accumulates dirt at the bottom of the reservoir and the condensing element never requires cleaning.

An automatic choke and fast idle of the carburetor is now being used by Buick and DeSoto. The automatic choke control is now a separate unit on the Oldsmobile-8 Stromberg EE 1 carburetor. In the Oldsmobile-6, EX 23 carburetor and the Reo-8, EE 23 double-barrel unit, part of the automatic choke is built into the throttle valve body. The thermostatic unit is incorporated in the manifold riser where it obtains heat from the exhaust gases. Both carburetors have the stepped cam for fast idle control. Ford is using a dual carburetor with a manifold of the "over-and-under" type, each branch feeding two center cylinders on one side and two end cylinders on the other. The Stromberg model EE 1 used incorporates such features as the accelerating pump, economizer and a semi-automatic choke with an offset butterfly and a flat suction valve therein. A limited number of Fords are being equipped with Bracke-Holley self-feeding carburetors. Hudson now uses down draft.

The hot spot in the Packard-12 manifold has been made removable to facilitate service operations. The Oldsmobile-8 employs a three port down-slope intake manifold. Hudson, Terraplane, Auburn and the Chevrolet truck now provide thermostatic control of the intake heating.

Graham's De Luxe eight has a supercharged 3¼ x 4 in., 265.46 cu. in., 6.7-1 compression ratio, 8-cylinder engine developing 135 hp. at 4000 r.p.m. and 210 lb. ft. torque at 2400. A centrifugal blower is mounted between the downdraft carburetor and the intake manifold, having a high-strength aluminum alloy rotor within a water-jacketed cover. It is driven off the rear end of the water pump shaft by a Cone worm gear drive with a ratio of 1-4.7 or 1-5.75 with the crankshaft. The vertical rotor shaft and gearing are fed by pressure lubrication.

The glass bowl has been eliminated from the AC fuel pump which is now more compact. The strainer and air dome are integral parts of the pump instead of being attached as heretofore. Ford is now using an AC pump of the lever arm type.

Packard has now combined the gas tank filler and tail light bracket on the left rear fender, with a flexible connection to the tank. Studebaker has a dome-shaped tank vent provided with a series of horizontal baffle plates with staggered openings. A cork float is suspended below the unit and if the tank is full or a swash occurs the float acts as a valve and seals off the central opening of the bottom baffle plate. A baffle in the Pontiac tank filler safeguards against gasoline theft. Experience with butane gas on the West Coast in which it is sometimes used as a truck body refrigerant before being fed to the engine, is an interesting development. A mixing valve has been developed by Ensign and the compression ratio increased to 6-1.

Mufflers packed with sound absorbing material have been improved by Burgess by incorporating tuned resonators. The combination of the two principles permits handling the wide range of frequencies encountered in exhaust work. This combination is used on the Packard-8. Flexible couplings are provided between the muffler and the powerplant by Packard

to prevent transmission of noise and vibration. All tail pipes are tuned for minimum exhaust noise. Studebaker and La-Fayette mount the muffler assemblies in rubber. Chevrolet has a diffusion type muffler consisting of three tubes with twelve surrounding chambers.

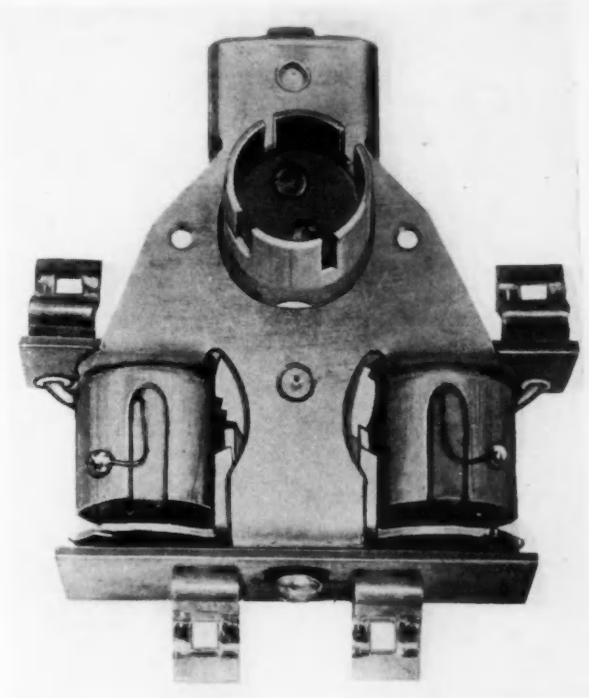
Electrical System

Current regulation with lamp load control is being used by Cadillac and Oldsmobile to provide a higher charging rate when the lights are turned on. The control and the resistance unit are in series with the shunt field. In the case of Cadillac, the regulator armature is carried on a bi-metal hinge which when heated furnishes a force opposing the regulator spring tension and causes the regulator to operate at a lower current when hot. This takes care of increasing the cold output of cars driven for only a short time per day and to decrease it when hot to prevent overheating the generator and overcharging the battery on cars more continually in service. A current limit thermostat is incorporated consisting of a bi-metal blade in series with the light circuit, completing it through two silver contacts held closed at ordinary temperature by the inherent spring pressure of the bi-metal unit. Current flowing through it generates heat and the design and adjustment are such that when 20 amp. flows with an ambient temperature of 210 deg. fahr., it will cause the contacts to open, limiting current flow should a short circuit occur. The maximum generator charging rate of the Oldsmobile is now at a higher car speed than on the previous models. DeSoto has automatic voltage regulation in addition to third brush. The Dyneto generator on Packard is provided with a screened-horn type air intake and a suction outlet for more effective cooling. Hudson and Terraplane incorporate radial fan plates on the back of the generator pulley to draw air through the generator from rear to front. A differential winding and voltage control are used. Auburn provides a suction fan within the generator. Dual automatic starting is provided by Buick in which the engine is started after turning the ignition switch and depressing the accelerator or pulling down the hand throttle control. The latter operation partly opens the throttle and at the same time operates a relay switch closing the solenoid control circuit but which is opened when the generator is charging. It is impossible to use a starter when the ignition is locked.

As soon as the engine starts the solenoid circuit is automatically broken by a vacuum switch which in turn is held open by a mechanical latch. Unless unlatched by returning the accelerator pedal to normal, the starting gear will not re-engage.

Starter button control on the instrument panel is now provided by DeSoto, Hudson, Terraplane, and Graham. Bendix Startix is used on the Auburn Custom 6 and 8, Franklin-6, Pierce-Arrow, Reo S DeLuxe and Studebaker. It is optional on Continental, Hupmobile, Packard and other Reo models.

The Bendix starter drive spring has the first coil wound with a varying reduction in diameter permitting the two end coils to be fully supported and obviating the necessity of spring support clips. This also allows concentric machining of the screw shaft. On the Chevrolet, Pontiac and Hudson a "barrel" type Bendix drive is used permitting the use of a nine-tooth, 10-12 pitch pinion mounted axially with the armature shaft. The drive head has an extended portion of reduced diameter and on which a triple-threaded sleeve constrained to move longitudinally from the pinion is loosely mounted without the customary compression sleeve. An anti-drift spring maintains the pinion in its demeshed position except when starting.



Studebaker magnetic ratchet mechanism for tilting head-lamp beam

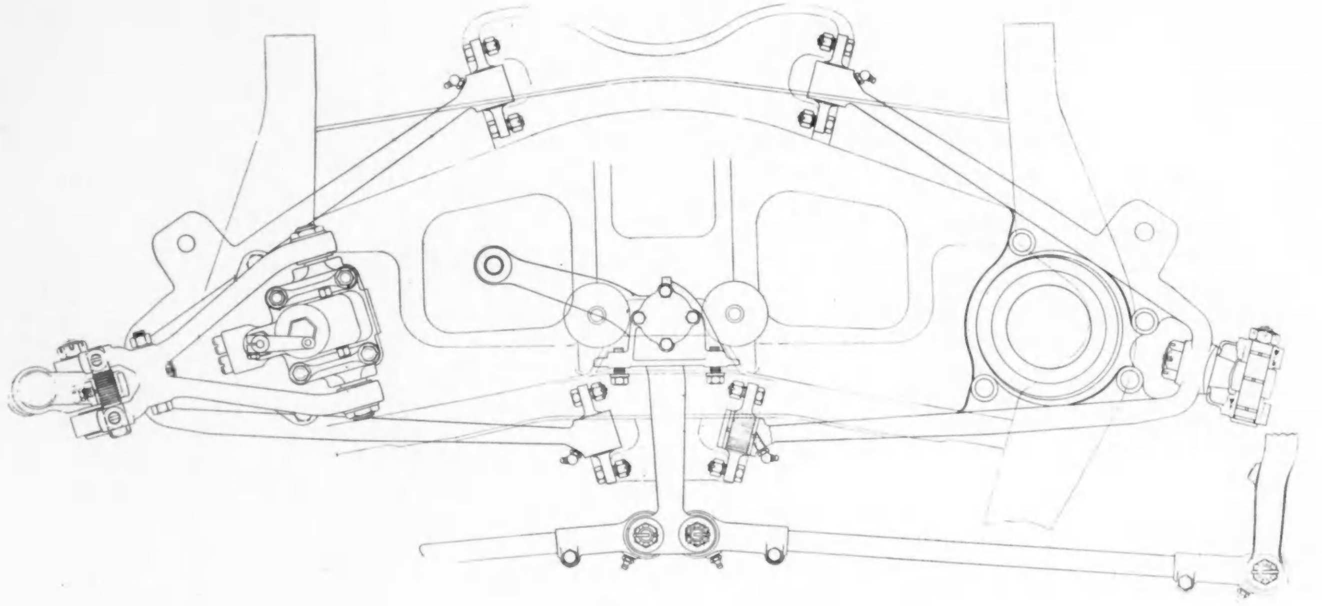
Chrysler Imperial and 8 and Pontiac have coincidental starters operated by the accelerator and a vacuum switch. Nash uses the clutch pedal instead. An octane selector is mounted at the left side of the Buick instrument board for spark setting in addition to automatic spark advance of the vacuum type, also adopted by Pontiac with a "gaselector" or manual distributor adjuster. Reduction in vacuum allows the distributor to retard itself by the return spring. The vacuum connection is just below the carburetor butterfly preventing suction of the intake manifold from advancing the spark with an idling engine.

On the Packard-12 the coils are re-located on the cylinder block from the dash to shorten the high tension lead and eliminate radio interference.

To check spark timing in service, Chevrolet utilizes a neon timing light placed in No. 1 plug circuit to illuminate a pointer in an opening on the bell housing front and check stroboscopically the relative position of a bright steel ball in the flywheel rim. The Lincoln ignition keys are not numbered, the designation being located on the barrel of the lock as a safety feature to prevent theft. Battery capacities have been increased in many instances. Buick battery terminals are made of a lead antimony alloy which are non-corrosive.

Engine Mounting

The Studebaker front engine mountings are of the bonded rubber-to-metal type set at an angle on the front cross member. The Dictator rear supports are a similar type, closely nested together under the free-wheeling housing. The Commander and President rear support consists of a plate interposed between the clutch housing and the transmission and with a rubber cone at each side. Oldsmobile has changed from the single high mounting point at the front to a lower



Plan view Cadillac independent wheel suspension showing threaded bolt connections and steering control

angular mounting on each side. The rear supports have been changed to a side mounting instead of the previous angular disposition. The front support of the Hudson and Terraplane consists of a rubber cup resting on the frame K member at each side and a rubber block under the back end of the clutch housing. An adjustable arm supported at each side by the frame X member bears against each side of the transmission case through a rubber block to stabilize the power plant in the frame.

Buick retains the five point with the front supports now resting on the forward, inturned extension of the X member. The front support of the Graham-6 consists of rubber-bushed links at each side, diagonally disposed so that their centerlines pass through the oscillation center. The rear mounting of the 6 and 8 is provided by two diagonally placed brackets with rubber blocks at each side of the transmission and mounted on a cross member in the X.

Clutch

Needle bearings have been introduced into the clutch release levers to reduce friction. Borg & Beck attains this end without the use of anti-friction bearings and obviating the need of lubrication. When the release lever is moved forward, its fulcrum pin, lying snug in the pocket of the lever, rolls along the forward flat surface of the broached eyebolt hole. There is ample clearance between the pin and the remainder of the hole to permit sufficient rolling motion for complete release. At the outer end of the lever, direct contact between it and the pressure plate lug is eliminated by the interposition of a 3/32 in. plate having rounded corners acting as a strut under compression to transfer the load from the pressure plate lug to the lever. Comparative tests up to 2,000,000 engagements in the laboratory and on the road showed no measurable change in friction and negligible wear. The Plymouth and Dodge release levers operate against floating blocks with knife edges.

A hardened steel throw-out thrust collar has been substituted by Oldsmobile for the former cast-iron, eliminating the "dragging-in" of the three throw-out fingers, a condition that required additional pedal pressure. The fingers now have knife edge fulcrums.

Long has introduced two heavy-duty clutches in which deflection and friction losses have been reduced. Six forged steel release levers with hardened button inserts to contact with the thrust bearing are mounted on needle bearings at the fulcrum and pressure plate lug. The fulcrum forks are held in the cover plate on spherical seats. The pressure plates are exceptionally heavy for better heat dissipation and to withstand hard usage. The driven member incorporates a "cushion plate" arrangement. The flywheel lining rivets directly to the flat-driven disc while the pressure plate lining rivets directly to a number of formed clock spring-steel segments which in turn are riveted to the disc. The facings are always flat and give a 100 per cent bearing at all times. With the coming of the greater number of cylinders and more flexible mounting, better running balance is necessary. On the large clutches Long has halved its balance tolerances of a few years ago and nearly all the parts that go into the assembly are separately balanced. The Plymouth driven member has woven lining on the pressure plate side and molded lining on the other.

The cork inserts in the Hudson and Terraplane clutches have been increased considerably in number. The corks are given a heat treatment to increase their life and in cutting they are given a final trim of ½ deg. of eccentricity to provide smoother engagement. The steel flywheel has been increased in thickness for stiffness, the clutch cover heavily ribbed for rigidity. The pressure plate is now forged and the torsional drive springs are pre-set. A new compound has

been developed for clutch lubrication called "Hudsonite." Spicer has developed a metallic facing for the driven plate, running without oil and replacing the asbestos lining. A slightly larger clutch is required due to the lower coefficient of friction. The average car can be started in high on the level or slight upgrades.

There has been considerable activity with centrifugal clutches. The Spicer Powerflo clutch can be converted to the conventional type by means of a control button on the instrument board, the conversion being by mechanical means or a vacuum cylinder. The Long Tri-Vac clutch utilizes a vacuum cylinder for conversion which is in continual communication with the intake manifold and providing automatic operation. This method is desirable to enable the use of the engine as a brake, to permit pushing the car for cranking a dead engine and to prevent undue slipping of the clutch when starting in high gear or when the engine speed is pulled down to the slipping range on a grade.

Some feel that a centrifugal unit is not yet perfected due to the difficulty in overcoming a back lash noise which results from the more sudden take-up of the play in the drive than occurs with foot operation. This only occurs at very low gear speeds.

The Bragg-Kliesrath automatic clutch control now incorporates a compensator by means of which the adjustment is automatically maintained independent of clutch facing wear and is used by Chrysler, DeSoto, Dodge, Plymouth, and Auburn Custom-8. The compensator valve is normally closed by its self-contained spring and the balance of this spring and the clutch spring load controls the compensating function. Auburn combines the free-wheeling and clutch controls so they become operative or inoperative simultaneously.

Transmission

The Reo self shifter, consisting of a two speed and reverse unit, controlled from the instrument board, in series with a two speed internal gear reduction is standard and on the Royale and optional on Model S. Direct drive of the automatic unit is attained by centrifugal weights acting on a multiple disc clutch. The transmission is noteworthy for its constant torque and the lower speed of reduction engagement than the high-speed engagement when accelerating. The Mono-Drive which automatically changes ratios when the accelerator pedal is released, is being used on the Stout railplane.

Buick, Oldsmobile and Nash retain their previous synchromesh construction, but have changed over the first and reverse gears to the helical type in conjunction with a helical spline on the main shaft. Hudson and Terraplane provide a multiple ball thrust between the main stem gear and the main shaft. Low and reverse gears are automatically demeshed when second and high are engaged or when in neutral. The main shaft is mounted on needle bearings. Lubrication is assisted by a provision incorporated in the constant mesh gears to draw oil through them instead of permitting it to be thrown off by centrifugal force. Hudson and Terraplane have dropped free wheeling, Graham furnishes it as optional while other previous users retain it.

Fuller has developed a two speed auxiliary unit which is remarkably compact due to the telescoping of the two main shafts. A herringbone gear sliding on the splined main shaft carries the bushed countershaft gear with it. When shifted forward the stem gear is engaged to effect direct drive; the countershaft gear in moving to the rear engages a clutch member integral with the countershaft and thereby effects the reduction drive.

Universal Joints

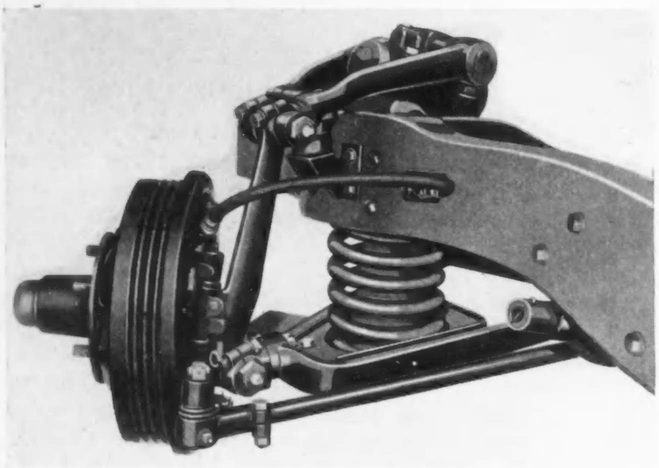
The elimination of lubrication in universal joints is the essential requirement, this being reflected in the widespread use of needle bearings. Rubber universal joints reappearing in the Nash line are of the Timken type but made by Nash in which four equally spaced rubber blocks are held between two stamped steel members. One pair of opposed blocks attached to the spider arms of the propeller shaft, the other to the transmission or the rear axle shaft. Cadillac is using an open propeller shaft of large diameter. Its length is decreased by the use of a forward shaft or stub carried on ball bearings within a tubular extension at the rear of the transmission and which also acts as the rear power plant support through a rubber ring. Mechanic's joints are used by Cadillac, LaSalle, Studebaker and Auburn. The Universal Products joints are standard equipment on Plymouth, Dodge, DeSoto, Hupmobile and Pierce-Arrow. Spicer is providing interaxle needle bearing assemblies for four-wheel bodies capable of taking care of angularities up to 45 deg. Oldsmobile, Hudson, Terraplane, Graham, Chrysler-8, Continental, Packard, Lincoln, and Duesenberg are equipped with Spicer joints.

Hudson and Terraplane utilize needle bearings and incorporate a relief valve in the joints to prevent damage to the oil seal when extremely high pressure is used in forcing in the lubricant and also to indicate when the joint is filled. Buick is now using a tubular propeller-shaft.

Axles and Braking System

While Cadillac has eliminated the torque tube, Buick still retains it. Pierce-Arrow has eliminated the torque arm in favor of the Hotchkiss drive to eliminate considerable un-

Oldsmobile hydraulic service brake with single piston. Mechanical additions permit cable hook-up with parking lever



Dodge individual wheel suspension with rubber bumper within spring and side rail

sprung weight with corresponding improvement in riding. All axles are of the hypoid type with a 2 in. pinion offset. The track of all Buick rear axles is 60½ in. The Studebaker-6 has 60 in. and the Eights have 61¼ in. In the Salisbury axles used on Austin, Continental, Graham, Hupmobile (hypoid) and the small Nash, the former independent differential carrier and banjo housing type have been superseded by a one-piece assembly with tubes pressed in and welded to the malleable iron center housing. The differential bearing supports are an integral part of the housing and their spreading under load is eliminated. The axle is of lesser weight and the construction does not lend itself to tinkering in the field. Assembly is made from accurate cone measurements for each individual gear set with special micrometer gages designed for the purpose.

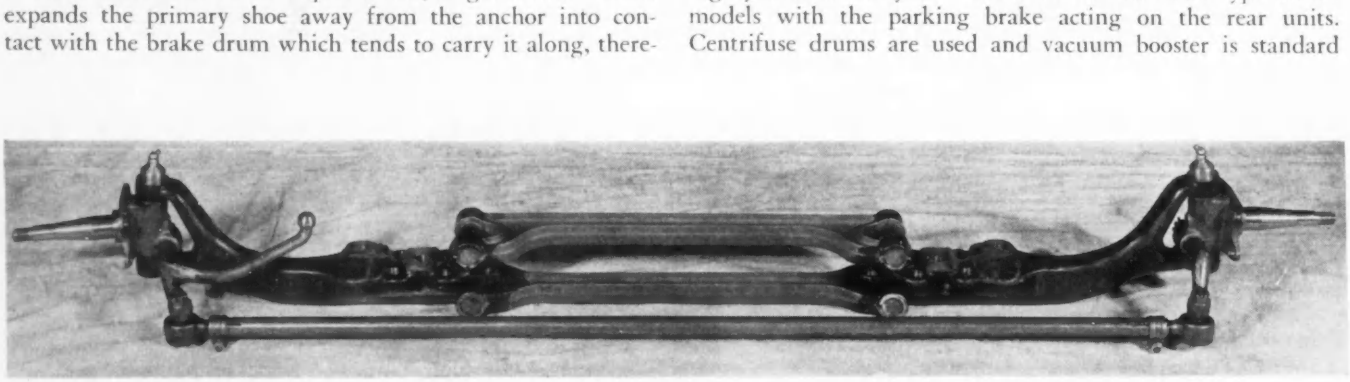
The Plymouth ring gear is located at the center of the axle with the pinion offset for better balancing the weight at each end. Auburn's dual ratio axle (3.4-1 and 5.1-1) continues on the Custom-8. A multiple disc synchro-shift clutch insures quiet meshing of the selector sleeve. The shifting lever control is now mounted on the steering column. A double-row wheel bearing is now used on the Chevrolet truck axle.

Wider spacing of the front wheel bearings accounts for the redesigned spindles on Hudson and Terraplane. A ball-bearing tie rod is used. There are instances where individual wheel suspension has called for a redesign of the wheel-bearing layout. Chrysler and DeSoto now use a heat-treated, alloy steel, tubular front axle center.

The Bendix Duo Servo "equal action, single anchor" brake expands the primary shoe away from the anchor into contact with the brake drum which tends to carry it along, thereby bringing the second shoe into contact. The cam action in front and rear brakes is identical and provides synchronization of braking effort. The connection between the two shoes—which are identical—is by the adjustment screw. The cam lever is operated directly by cable. Any degree of controllability desired can be attained by the selection of the linings for the two shoes. By differing their frictional characteristics together with proportioning of the operating levers and the angles through which they move, it is possible to provide practically any desired deceleration curve. Protection of the interior has been much improved by the use of seals guarding against entry of water and foreign matter, yet permitting egress of any accumulation of brake lining dust. On the assembly line adjustment is accomplished by using a dummy drum and involves a permanent location of the one anchor, the eccentric and the adjustment screw. The latter permits quick and easy final balance. To compensate for wear, adjustment involves merely a turning of the adjusting screw and setting of the eccentric. A stamped steel dirt shield on the Chevrolet backing plate is placed close to the shoes. Rear brakes are now cable-operated.

The "full power" Stewart-Warner braking system is continued on all Pierce-Arrow models. On the Nash Ambassador the rear cable conduits are automatically lubricated by the Bijur system. For equal conduit curvature under axle roll, Hudson and Terraplane connect the brake cable to the upper portion of the front brake drum and to the lower portion of the rear. The parking brake lever is in the center because the cut-away bottom of the front door prevents its location on the left. Buick uses a short cross shaft from which diagonal brake rods parallelling the X member extend to the cable conduits reaching from the frame to the wheels. The braking area has been increased 30 per cent by making the length of the "reverse" brake shoe equal to that of the "forward" one. The new cast-iron drums have machined cooling fins on the exterior. Pierce-Arrow retains the high carbon continuously rolled and ribbed section drum without weld, except where it is attached to the pressed steel back. Graham now has high carbon ribbed steel drums. In many cases the drum width has been increased due to small rim diameters. In the case of DeSoto the drums are one-third wider.

Increased use of hydraulic brakes is evident. Oldsmobile uses a single anchor two shoe, self-energizing type with a single piston instead of the customary two by allowing the cylinder to actuate one shoe. This is a Bendix-Hydraulic unit incorporating many other parts of the "equal action" brake. The same cam levers are provided on the rear brakes and connect by cables and rods to the parking brake lever. The two brake rods are crossed similar to the diagonal braking system of last year. Auburn uses the same type on all models with the parking brake acting on the rear units. Centrifuse drums are used and vacuum booster is standard



Axleflex construction used by Hudson and Essex Terraplane

on the Custom models. The Dodge Centrifuse drums have four corrugations serving as flanges. Pontiac drums are of high carbon manganese alloy steel with radiating flanges.

The vacuum booster brake is used by Buick and the control valve is mounted separately instead of in the pedal rod and is operated by an equalizer attached to the rod. This results in multiplication of the valve reaction through the equalizer giving a more gradual "feel" to the pedal and making the merger of power and physical effort very smooth. Vacuum admitted to the power cylinder also reaches one side of a diaphragm tending to close the control valve unless additional force be applied. With 16 in. of vacuum it takes 10 lb. pull on the diaphragm stem to crack the valve and 60 lb. to hold it wide open. Packard locates the vacuum control valve on the left side of the instrument board while Lincoln places it on the steering column. The Lincoln vacuum line is now connected to the inlet header instead of the right intake manifold.

As a result of constant research and investigation linings have been made available in which fade-out and rapid wear have been eliminated and constancy of performance brought near a state of perfection. World Bestos is making a molded lining from a new formula, giving performance and deceleration curves that practically correspond to the theoretical. There is a tendency, especially in the replacement field, to go back to woven linings, but entirely different from the old types. World Bestos claims to have discovered a new oil compound which thoroughly impregnates the product and is heat resistant. The compound can be boiled in an open receptacle up to 800 deg. fahr. without flashing. Cadillac is using a woven lining while Lincoln places Rusco Durak molded linings on both shoes. Multibestos is furnishing "tailored sets" for the replacement trade grouped according to brake mechanisms and service conditions. Seven different types of friction material are available, in some cases being used singly and in others in combination, resulting in a production and prearrangement of materials without guess work.

The friction value of brake lining after it is in use is automatically indicated on the Raybestos-Tilden friction meter. The indicated frictional value is the resultant of the torque of a small electric motor and the pressure exerted by the operator of the instrument against the lining. The friction tip is driven through a spiral cam on which the follower locates itself.

The 3-cylinder Westinghouse air compressor delivers 12 cu. ft. at 1250 r.p.m., weighs 32 lb. complete and has a counter-balanced crankshaft, aluminum crankcase, cylinder block and head and Ni-Resist liners, pistons and valve inserts. Compressor drive by the same double V-belt that drives the cooling fan is used on the Hercules Diesel. Some of the Hall-Scott engines drive directly from the fan or crankshaft. Wagner Electric is building a vacuum operated compressor in which a large double-acting vacuum piston actuates a small single-acting compressor piston at each side on the same rod. The foot valve is suspended in the pedal brake rod.

Wheels and Tires

The steel spoke artillery type of wheel is very popular, with the hub of the stamping much larger in diameter and used in combination with a large chromium hub cap. It is used by Buick, Oldsmobile, Dodge and Graham. Graham provides wire wheels as extra optional equipment while Auburn, Plymouth and Pontiac standardize on them. DeSoto has steel disc wheels as standard and the steel spoke artillery optional. The spare in a metal cover is mounted on, and at an angle conforming to, the taper of the body tail similar to Chrysler. On the coupe the spare tire is concealed within the rear deck. This construction is also followed in the Silver Arrow model of Pierce-Arrow. There now remains little intervening space between the popular 16 in. rim and the large hub.

Chevrolet and Pontiac wheel suspension unit with wheel mounted on a rearwardly extending lever

To obtain quietness on straightaways and sharp turns, at least equal to the 1933 tire and with equal carcass, bead and tread life at substantially lower inflation pressure, a radical departure from conventional design was necessary. Independently sprung wheels also added to the problem. The U. S. Rubber pioneered such developments with the result that the present tire shows a flatter tread profile, its shoulders, block and rib edges are rounded and it has four rows in the tread design instead of five. The carcass and bead constructions have been strengthened to adequately resist the greater flexing stresses imposed by lower inflation. The 16 in. Royal is used on Buick, Oldsmobile and Graham. The trend is definitely toward low-pressure tires of 16 in. diameter used on wider rims. Pressures are mostly 25 lb. compared to 35-40 last year. For instance the 6.50-16 tire is used on a 4.50 rim whereas 6.50-17 tire of last year was used on a 3.62 width; similarly a 7.50 section on a 5.50 width as compared to the 4.19 for the previous 17. Greater sidewise and in some cases improved front end stability have resulted. More accurate balancing of front wheel assemblies including hub, brake drum, wheel, shoe and tube aims to reduce front end tramp at high speed. A considerable number of car manufacturers have established very strict specifications covering front wheel assembly balance as well as eccentricity for true running.

Ford, Chevrolet and Plymouth (6.00-16 optional) continue on 17-in. tires as well as Packard, Cadillac and Pierce-Arrow. The rest are practically all on 16-in. tires. The white side wall is in little demand. The lot of the tire manufacturers is not an easy one when they are being asked to provide tires that will not throw gravel on gravel roads and to subdue the thump in going over expansion joints in concrete pavements. The result of present and such future requirements is less non-skid and more all-rib effect in the tread design.

Goodrich is making a "tear-proof" inner tube utilizing two different stocks, the inner periphery being manufactured to

reduce the abrasive action caused by rims and the outside to resist tear in case of flat tires. Goodrich, Firestone and Goodyear are supplying rubber valve stems. Firestone furthermore places a special compounded coating on the inside of its "Sealtyte" tubes to close the pores of the rubber.

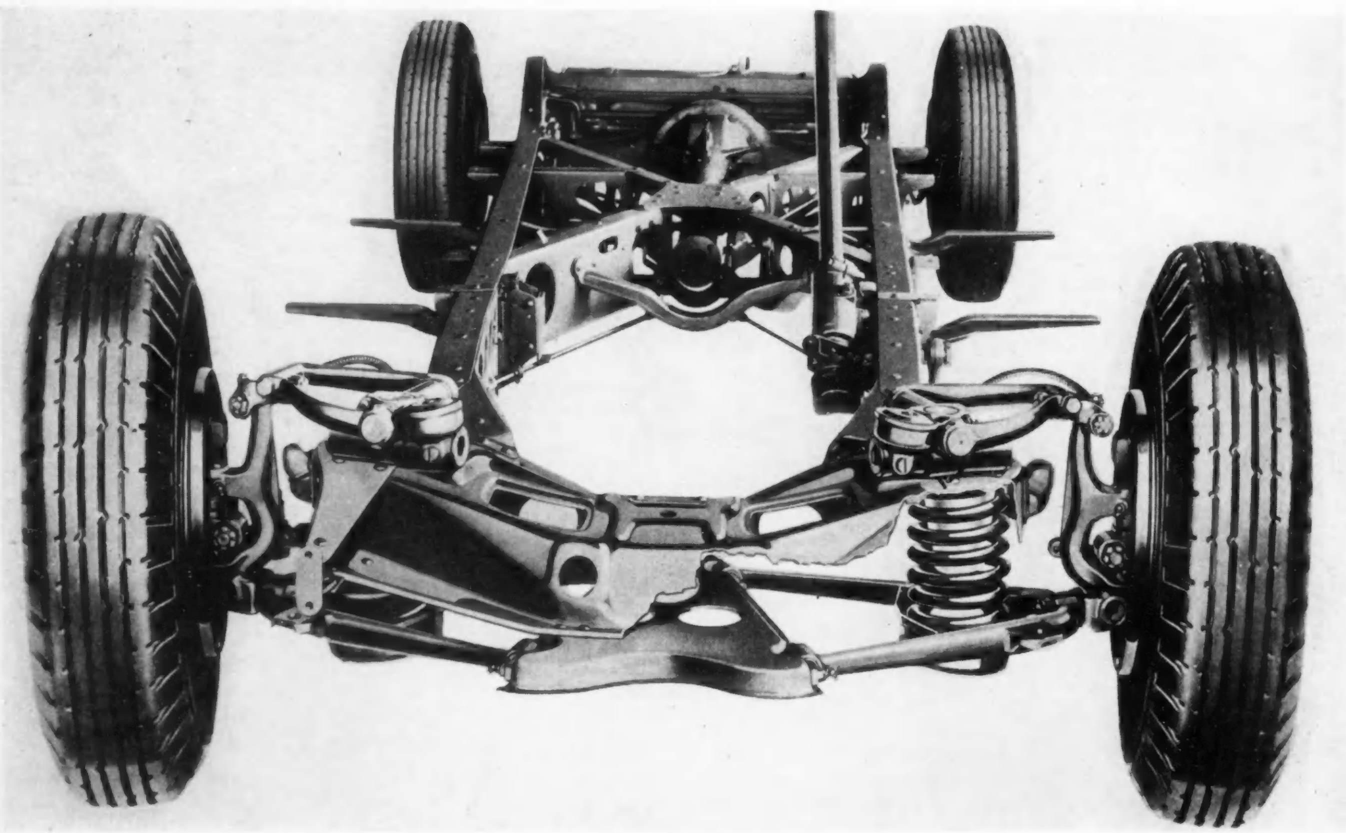
Suspension

Individual wheel suspension which is the major development in chassis design is shown in three types. Buick, Cadillac, Dodge, Oldsmobile and Plymouth utilize a pair of drop-forged forked arms, the lower one being longer than the upper to maintain constant tread. The arms straddle the frame and front cross member, the upper one being anchored to a double-acting shock-absorber located on the top of the frame. The lower widespread arm which takes most of the brake torque is pivotally secured to the bottom of the cross member. A fork, with integral threaded shank and castle nut securing it to each arm, is pivotally attached to the steering knuckle forging, top and bottom. All joints of the linkage, except at the shock absorber, are of the threaded spring bolt type. A vertical coil spring at each side is located between the frame and the lower arm which incorporates a jack pad. For spring material Cadillac uses S.A.E. No. 9255 steel. The axes of all these joints on the same side of the chassis are parallel and in a slanting direction, converging toward the rear of the chassis. A rubber bumper within the coil spring prevents striking-through and a bumper on the outside of the frame rail limits the downward movement at each side. In the Plymouth and Dodge construction, caster angle adjustment is obtained by rotation of the steering knuckle top bolt while shims behind the upper fork permit camber variation. The Chrysler-6 will incorporate individual suspension.

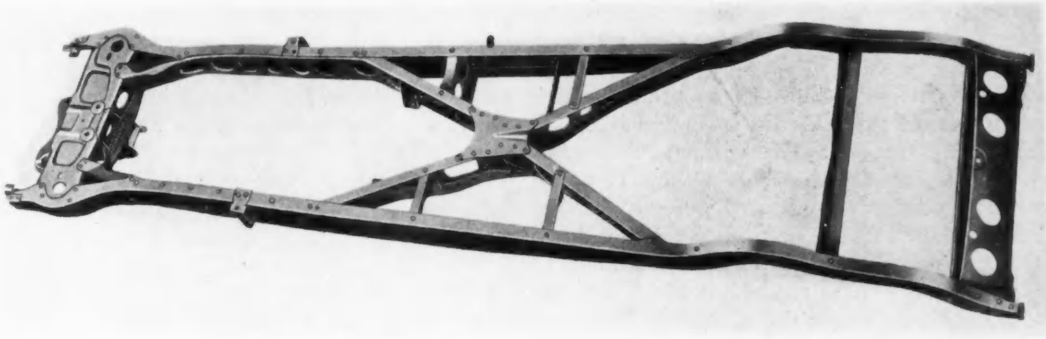
Steering is accomplished in the General Motors group by means of a bell crank to which the fore and aft drag link is secured. A short drag link extends to the steering arm at each wheel spindle. Their inner balls are close to the axes of the lower forked arm pivots.

In the Dodge and Plymouth, cross steer is used and attaches to a central lever which, as in the case of the General Motors' bell crank, is mounted on anti-friction bearings.

Chevrolet and Pontiac are using the Dubonnet principle, each front wheel being attached to the end of a rearwardly extending lever whose pivot enters a sealed housing where dual coil springs and a two-way shock-absorber mechanism control the wheel movement. The wheel, crank arm and housing swivel as a unit about a king pin by which each assembly is attached to a rugged frame cross member. Since the steering mechanism is attached to the housing units, steering action is entirely unaffected by wheel movement. Within the housing the wheel support lever has two arms at the forward side each actuating a shock-absorber plunger, the top one cushioning upward wheel movement and the lower one controlling downward travel. A rearwardly extending hooked arm supports the steel collar at the base of the springs, through the intermediary of a needle bearing mounted pin with flattened ends. A hardened tubular guide secured to the collar extends upwardly and is received in a spherical headed sleeve against whose upper flange the outer spring thrust is taken and whose lower flange engages with the inner spring when it comes into action. A threaded cap with



Independent front wheel suspension on 1934 Buick



Cadillac X-member frame. Rugged front cross member takes the suspension system and radiator mounting

a central spherical seat takes the thrust of the sleeve head and permits the necessary oscillation of the sleeve-guide unit. The threaded cap permits adjustment to compensate for variations which affect the car height. The large outer spring provides a unit deflection at the wheel of approximately 115 lb. per in. through a range of 3⅝ in. of wheel travel below normal to 1⅞ in. above normal position. Through the remainder of the wheel travel range of 1 in. upward, the smaller inner spring comes into action building up pressure at the wheel at the rate of approximately 540 lb. per in. The brake flange and anchor plates are freely mounted on the wheel spindle and correct geometrical relation between the spring unit and the brake mechanism is maintained by means of a radius rod anchoring to the bottom of the housing. Pontiac claims a 60 per cent reduction in unsprung weight which is now reduced to 100 lb. per front wheel. The working parts within the housing are automatically lubricated by the shock-absorber oil.

Hudson and Terraplane provide an "axleflex" construction as optional, interchanging with the standard front springs and shock absorbers. Each axle end, within the spring seats, terminates in a pair of vertically disposed bosses. Two forged links of I-beam section connect the bosses in parallelogram fashion through needle bearing joints. A conventional one-piece tie rod is used as well as the regular drag link and axle arm for steering. The wheels are always parallel and in making a turn the outside spring is compressed and the inner one opened up due to the raising of the outside spring pad and the lowering of the inner. The frame and body are thus automatically "banked" on a turn. The normally vertical position of the wheels is maintained by the parallelogram construction and the torsional resistance of the springs. This Baker type suspension is being offered as optional equipment by Nash and LaFayette.

A new version of the conventional suspension system is incorporated in the DeSoto and Chrysler models. In each case the engine has been moved forward 20 in. over the front axle thereby increasing the load on the front springs. At the same time the engine is moved further from the center of gravity of the vehicle, the moment of inertia is increased and pitching decreased. The Chrysler-8 and Imperial have 44 x 2¼ in. front springs, the rears being 53⅜ and 52½ x 2 in. respectively.

Buick has moved its engine 2 in. ahead for better weight distribution. The sidesway eliminator introduced by Hupmobile continues thereon and has been incorporated in the Oldsmobile, Buick and Cadillac. Oldsmobile places the cross bar between the two rear shock-absorbers whereas Buick and Cadillac connect the end levers with the axle by independent links inside the shock-absorber connections. Threaded spring bolts and the U-shackle remain popular. The Cadillac, Auburn and Dodge upper shackle bolts are mounted in rubber bushings under compression. The two threaded bolts of the Chevrolet shackle are held in the side links with a taper fit and cork seals between them and the spring.

In discarding the torque tube to minimize road vibration, Cadillac has adopted the Hotchkiss drive. Rear springs are perfectly flat under normal load and are 66 in. long on the 146 in. and 154 in. wheel base models (60 in. on all others) and have "Berlin" eyes to avoid rear axle geometry errors and to improve steering at high speed. Cadillac claims leaf springs are desirable at the rear for their interleaf friction as against the frictionless helicals, to control the heavier unsprung parts. The Cadillac rear springs are not lubricated in the field. A strip of rubberized fabric is placed between the first and second leaves. Square bronze inserts with graphite filled depressions are placed between all other leaves. The springs are protected by metal covers. Cadillac terms this construction dry lubrication of the springs.

The front end of the Nash, LaFayette, Chrysler and Dodge rear springs are supported in rubber bushings. Chevrolet has the "Inlox" bushing. The front end of the Auburn left spring is provided with a kick shackle having three rubber bushings. Metal spring covers are standard with a fabric covering between the spring and the metal, to retain lubrication and act as anti-squeak. Studebaker provides a felt liner. Anderson has introduced a fitting for metal covered springs whereby pressure lubrication can be had through a special clamping bracket at the service station. Hudson and Terraplane have a rubber insert between the rear axle housing pad and the spring main leaf to absorb road vibration. The rear springs are splayed and are now wider at front than at the rear, permitting flexible springs without excessive sidesway. An extra half leaf is added to the rear spring to absorb brake torque. The half leaf terminates in an eye and is secured to a clip fastened around the main and second leaves. The Ford rear spring is more flexible and the front and rear spring leaves are pointed preventing squeaking.

Frame

High torsional rigidity of the entire assembly and particularly of the front end characterizes the new frames. This is particularly necessary in the cars with individual wheel suspension. All cars using helical springs place an outwardly curved offset at the front where, with the front cross member, the spring is snugly housed. The cross member receives the shock absorbers, the lower forked arms and the radiator. The X-member forward portion forms a box section with the side rail and is offset inwardly to meet the front cross mem-

ber. In the Cadillac long wheelbase models, the rear arms of the X-member extend back over the rear kick-up to the end of the frame.

Pierce-Arrow has a double channel frame from end to end, the channels facing each other making a box section the full width of the flanges. The channels are welded together every 6 in. besides being riveted. Of the seven cross members three large tubular units are used, one just ahead of the radiator, another back of the transmission and a third large tube at the kick-up contour. The latter is bent upward and to the rear passing behind the heel board of the rear seat with ample propeller-shaft clearance. This is made possible by keeping the rear seat location constant in reference to the axle and varying the wheelbase rather than providing increased overhang with the longer bodies. Studebaker has also adopted box section side rails which with their X-member has considerably greater torsional stiffness over the previous design and weighing 17 lb. less in spite of being 3 in. longer.

On the Auburn-8 "X-plus-A" construction, a channel section is located in each side rail to form a box section from the X-member anchorage to each end. On the Auburn-6 there is a box section at the front only. Alphabetical designations have not yet been exhausted in view of the Chevrolet and Pontiac "Y-K" frame. This consists of the forward portion of the customary X terminating with the second cross member and its K-brace to form a central box tunnel. The Y continues to the front cross member making a box section with the side rail ahead of which the vertical webs are closed together. The king pin supports are part of the front cross member. The front spring units and wheel spindles are attached to them as a sub-assembly, the whole being subsequently united to the frame.

Control

Special equipment has been developed by Ross to grind a uniform width of cam groove to eliminate high spots which are likely to result from warpage in heat-treating, permitting closer adjustment and uniform action. In view of the desire on the part of light car manufacturers for less steering effort, Gemmer is producing a needle-bearing mounted roller-type gear with a one-piece housing to replace their previous worm and sector. The double roller used on heavy cars is now mounted on needle bearings. Easier steering is obtained on the Lincoln by the shorter steering arm. The Buick worm and roller type has the roller mounted on ball bearings. On the 60 and 90 series, the single-tooth roller has been changed to a double. On the DeSoto, Plymouth, Dodge and Chrysler the steering gear is located well forward providing a rakish angle of the column and permitting cross steer. On the DeSoto and Chrysler the drag link is ahead of the front axle with the gear on the front cross member.

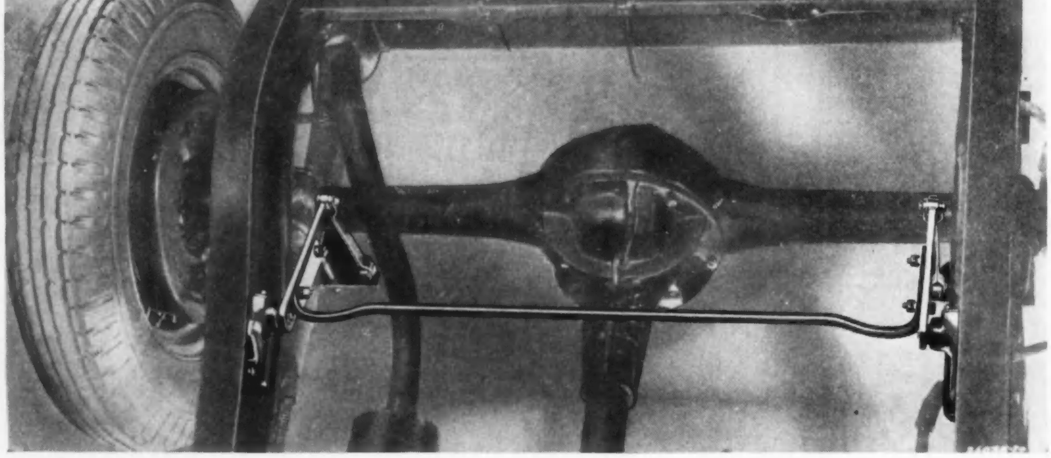
Packard and Studebaker steering wheels are colored to match the molding trim. Ivory colored wheels are supplied on the Graham De Luxe-6 and both 8's. Black wheels are standard with Auburn but walnut finish is supplied in the Custom. Auburn and Pontiac use a combination mechanical and ignition lock on the steering column.

With a truck load in excess of 8000 lb. on the front wheels, proper steering becomes a problem and Westinghouse has developed an air steering control comprising a double-acting cylinder controlled by a floating lever on the steering shaft arm. To avoid rods and shafting with a center or rear powerplant, Westinghouse has also developed an air-operated gear shift with a small H-gate control box near the operator and selector and shifting cylinders on the transmission cover plate together with a pilot cylinder and pilot control valves. Their remote throttle control is a miniature of the air-operated clutch device. Fuller has developed a transmission control for camel-back trucks consisting of two longitudinal shafts, one acting as a selector and the other as a shifter and being invulnerable to frame twist because of ball seat mountings.

Long has an automatic wear compensator which maintains the original clutch pedal and floor board clearance. The clutch pedal actuates a serrated hub through a segment of mating serrations on a C-shaped lever mounted in eccentric relation to the throw-out shaft. On the Federal house-to-house delivery truck, the master pedal when depressed throws out the clutch, sets the brakes and throttles the engine to idling through an automatic speed regulator actuated by the clutch.

Equipment

Bumpers have been redesigned to blend more completely with the front end appearance of cars, the drop center type being very popular. Full length rear bumpers are also more common. The Pierce-Arrow bar is in two halves, flared at



Stabilizers to prevent body sway used on 1934 Pontiac. One link at each side actuates shock - absorber and stabilizer cross bar.

the inside ends and joined at the gap by a center dropped ornament. Cadillac units a pair of superimposed bars of streamlined form to a central bullet shaped head at each side supported from the frame by telescoping tubes and coil springs therein. The Chrysler bumper consists of three curved, round-edged horizontal bars spaced one above the other, the center member being thin in comparison with the other two.

There is a trend to larger instruments and combining the smaller ones into one or two large units and in a few cases they are all combined with the speedometer. For the first time color on instrument dials is quite general with brown, green, cream, black or etching prevailing. A new effect is a finely striped dial. Translucent dials are generally used, giving a soft light at night without brilliant reflections and making it possible to read a dial just after sunset. The translucent part of the AC dial shows light green at night and dark green in the daytime. Nash provides a two-way switch which illuminates in one position the ignition lock whose tumbler is mounted in a translucent ring or the instruments in the other position. Package compartments are quite general, Graham providing three with ribbed aluminum doors with the opening handle below the edge of the panel. Chrysler utilizes airplane type instruments framed in chromium while Pontiac's are of the radio dial pointer type. The Auburn-8 instruments are grouped in a round dial the same size as a speedometer which on the Custom model has a telltale light that flashes red when the crankcase oil level reaches a low point. A tachometer is provided between the two dials. On the Custom-6 and 8 all knobs are of Catalin finish.

Smaller head-lamps are used in the effort to reduce wind resistance. The advent of the flanged fixed focus bulb pioneered by Tung-Sol and with a tolerance of the light source within 0.010 in. from perfect focus has made possible shortened focal length reflectors and smaller diameter lenses and housings, the former being generally spherical segments. A circular boss on the apex of the reflector holds the bulb flange by three unequally spaced spring-pressed pins which engage buttonhole slots in the flange. Tilting of the reflector in the vertical or horizontal planes is accomplished by an outside bottom and side adjusting screw in the Guide lamps. Housings are invariably bullet shaped. In the Studebaker head-lamps, two 32 cp. filaments are mounted side by side and dimming is taken care of by deflecting the light to the right instead of the customary depression when the toe button switch is operated. A switch on the instrument panel controls the vertical angle of the beam by changing the position of the bulb by means of a magnetic ratchet mechanism. The lowest position is for city driving and the upper two provide adjustment for rear seat load that might cause the beam to rise above horizontal. The Auburn Custom-8 provides a similar control. In the Hall "flex-beam," the left light beam is depressed for passing, the right beam remaining unchanged to give full illumination. The Oldsmobile and Buick "multi-beam" lamps provide crossed beam illumination in which light rays from the left head-lamp are deflected to the right side of the road and the rays of the right head-lamp to the left. In passing the beam of the right head-lamp is depressed. In the DeSoto, the "flex-beam" head-lamps, with three adjusting screws for aiming, are sunk into the front of the body with only the doors projecting. Chrysler has dual lamps at each side, one above the other and placed flush at the front.

The Studebaker and Pierce-Arrow tail lamps are built into the fenders and shed light on the gas tank filler. The Nash parking and tail lights are built and beautifully faired into the fenders. Oldsmobile trunk models have the bullet shaped tail lights mounted on the trunks. Relay-operated horns on the Packard-12 prevent corrosion at the horn button. Buick has "air-toned" horns while Pontiac's "electric whistle" has a $19\frac{1}{2}$-in. projector, mounted under the hood and furnished as twin units at extra cost.

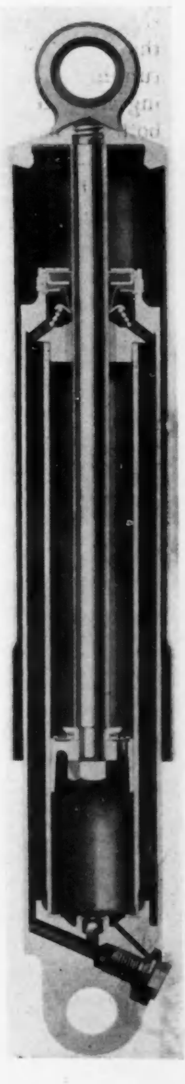
The direct-acting shock-absorber is a distinct improvement, permitting the use of low pressures as a sequel to large displacements, making the instrument easily controlled and more uniform in action. An extremely short orifice eliminates the need of a thermostatic viscosity control. The Spicer and Monroe units are both provided with a central working chamber attached to the axle head, surrounded by a reserve supply chamber with the piston and rod attached to the frame head. The Spicer unit is being used on Hudson, Terraplane, Reo and Auburn.

Ride control of all shock-absorbers is retained by Cadillac. The rear units incorporate inertia control, this being the first time that manual and automatic control have been combined. The new Houdaille shock-absorbers on Ford incorporate a thin disc with an aperture replacing each of the former valves. The Lincoln shock-absorber links are mounted in heavy cotton fabric impregnated with graphite.

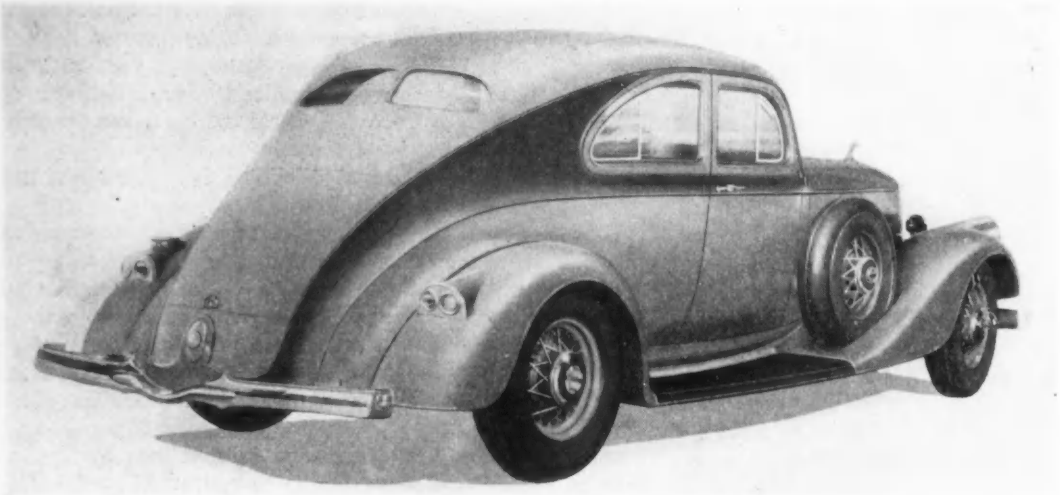
A compact steam heater has been developed by Delco Appliance consisting of a dash-mounted heating core and fan. The boiler consists of heavy copper tubing in the exhaust line with a supply and return line to the core. Steam pressure is automatically maintained by a control chamber governing the amount of water in circulation ($\frac{3}{4}$ oz. total).

Sheet Metal

In general front fenders are carried forward and down further, the width and depth of crowns have been generally increased. The Nash fenders have ribboned speed lines embossed in the skirts. A large radius at the wheel opening eliminates a flat panel effect. The Nash and Packard inturned edges form a gutter to carry water away, preventing its splashing the body. Hudson and Terraplane incorporate a fender screen to prevent gravel being thrown back against the fenders which have a greater clearance from the wheels.



Spicer direct-acting shock-absorber



Silver Arrow model of Pierce-Arrow in which the trend toward streamlining is emphasized particularly in the rear.

Studebaker uses a plate for this purpose on the streamline tail of the rear fender. Nash, DeSoto and Chrysler provide discs to close up the wheel opening of the rear fenders. The embossed crown of the Nash rear fender is given a reversed curvature near the running board to add to the streamline conception. The Chrysler and DeSoto fenders do not have full crowns as they merge directly into the front and tail of the body. The DeSoto front fender is separated from the running board. A number of cars include a chromium molding along the edge of the running board and extend it along both fenders.

There is a general trend in carrying the hoods rearward to the base of the windshield. Nash embosses the top surface with speed lines and the hood rolls over to meet the radiator front. Horizontal hood doors are used to a greater extent as well as a central chromium top strip extending from the radiator to the windshield base. Buick is providing four horizontal louvres almost the length of the hood with a narrow chromium bead along the edge. Chevrolet has three, graduated in length. Dodge uses horizontal louvres in three sets of three individual openings, the front ends slanting individually and in combination. Auburn employs three curved, tapered and staggered louvres. The De Luxe Plymouth has conventional louvres at the front and two horizontal doors at the rear. DeSoto and Chrysler use no conventional hood as the body is carried forward. Access to the engine is obtained by lifting a panel on the nose and top of the front end. Tappet adjustment can be made by removing a front-wheel housing panel giving access to the engine side. DeSoto provides horizontal louvres at each side of the engine compartment while Chrysler utilizes horizontal doors.

Bodies

The DeSoto and Chrysler "airflow" models are outstanding. In moving the engine ahead the rear seat is located in front of the rear axle, 20 in. ahead and lower than the previous model, permitting the seating of passengers between the two axles. There is a chassis frame for assembly purposes and the body side structure forming a truss with a minimum depth of 4 ft. reinforces it from front to rear. The rounded nose at the front and the curved roof over the windshield and at the rear where the large radius merges into a tapering tail, place these designs in the foremost rank of commercial streamlining production. The body sides are higher than usual for safety and appearance.

Most bodies have been made longer to give additional leg room from either or both seats. Rear body panels have been given greater slope as in the case of Buick, Studebaker and Dodge, the latter two having greater back flare. The Pierce-Arrow rear panel is given a reverse curve at the bottom of the flare, conforming to the fender crown contour. The Studebaker rear slope permits a deep recessing of the trunk. The upper body side panels are sloped inwardly giving a low and narrow effect. The Pierce-Arrow Silver Arrow design is retained in milder form in some of the body models.

Hudson and Terraplane retain the steel bottom to which the body structure is welded and attached to the frame at 30 points. Auburn has a metal, reinforced plate extending from the cowl to the rear of the frame. The cowl of which the instrument panel is a reinforcing member is welded to the plate as are the side quarters. The unit is directly bolted to the frame.

Ventilation

A number of new ventilating systems have been worked out. In the Ford and Lincoln method the window glass is raised to the top and an additional half turn of the regulator slides the glass horizontally to form a vertical opening through which air is drawn out by the forward motion of the car. The Nash and LaFayette front door glass is partly cut away at the top to form a vent when the window is closed. Closely fitted ventilating wings at the front serve also to close the vent as required. The rear quarter windows are pivoted and swing out. Packard has dropped the rear window ventilators. Pierce-Arrow has adopted a ventilator on the front and rear windows. On the Fisher bodies, deflectors are provided over the tips of the front ventilators to prevent entrance of draft, rain or snow when open. In the Plymouth, Dodge, Chrysler, Auburn, Hudson and Terraplane the divided front window may be lowered as a unit or the ventilating section operated independently. Control is by a single handle with the addition of a small lever or as in the case of Hudson and Terraplane the deflector is controlled by an independent regulator. The rear windows of

the Plymouth, Dodge, Chrysler and DeSoto are of the swinging type. The Auburn rear window can be slid back. The Plymouth and Auburn rear regulators are placed at the top where they do not interfere with the passengers. The DeSoto front seat construction permits air currents either from the cowl ventilator in summer or the heater in winter to pass under it to the rear compartment. Streamlining permits lowered front windows without introducing drafts and the cowl ventilators are more effective.

The Fisher bodies open the top cowl ventilator toward the windshield, tests proving that more air is directed into the body due to the reversed airflow with the conventional hood and windshield. The Auburn-8 cowl ventilator is provided with a catch basin with drain to enable driving in the rain. Ford and Buick ventilators have a deflector to more completely diffuse the entering air over the dash, pedals and floor boards. Studebaker uses a cowl of double construction bulging forward at both sides of the engine to give additional leg room and lessen drumming tendency.

The Plymouth and Dodge windshields are controlled by a strong concave steel "ribbon" which pushes the windshield out as it is unwound from the crank-operated reel and pulls it closed when winding. The Nash windshield wiper is driven through a flexible shaft from the engine camshaft and is mounted as in the case of Studebaker at the base of the windshield to provide up-sweep action. Hudson and Terraplane provide two intermediate windshield positions between full open and closed. DeSoto and Chrysler have divided V-windshields, each half being operated by its own crank. The total width is wider, increasing vision. The Auburn-6 windshield is permanently set and is without center strip.

Doors, Windows and Fittings

A common practice is the slanting of the front door to provide easier entrance. Ford De Luxe, Oldsmobile and Buick provide arm rests on both front doors with Chevrolet on the left only. Overhang of the door hinges has been shortened on the Oldsmobile and Buick to reduce wind noise and improve appearance. Auburn front doors have an additional dove tail at the top edge and all hinges are drop forged steel with hardened steel pins. Hardened steel guides are incorporated in the rattleproof type door locks. As an anti-theft measure, the Chevrolet door keys bear no numbers, same being placed on an integral tab accompanying the key for the owner's memorandum.

To provide greater entrance height, the Briggs Ford taxicab body has an arched rear door. Height is obtained in the Studebaker bodies by running the top door line considerably above the top of the rear quarter window. A smooth exterior is obtained by the elimination of the conventional drip molding and instead a rubber seal is placed around the inside contour of the door. DeSoto and Chrysler models have likewise eliminated the drip molding.

The DeSoto and Chrysler front doors hinge at the front while the rear doors hinge at the rear. The rear door has a diagonal slope symmetrical with the windshield pillar angle at the front door. The rear quarter window conforms to the large roof radius and a wide double window is provided at the rear.

The Buick door and body panels are insulated with asphaltum board cemented to the metal. The shrouds are provided with ½-in. felt glued to the inside surface. The tool box and rear seat pan are covered with ¼-in. felt. Seapak made from Kapok fibre combined with a small amount of rope and rag stock for strength and fireproofed is used for dash heat and noise insulation by Oldsmobile, Studebaker and White trucks. Pierce-Arrow has a 1⅜-in. thickness, and also uses it on the cowl, body panels and in the roof. Due to its lightness, about 30 lb. can be saved.

Packard incorporates a garnish molding on the top of the front seat back. The Graham moldings have a three-rib design while DeSoto incorporates four. The Lincoln moldings are of solid mahogany with narrow panels of lighter shade and diamond pattern.

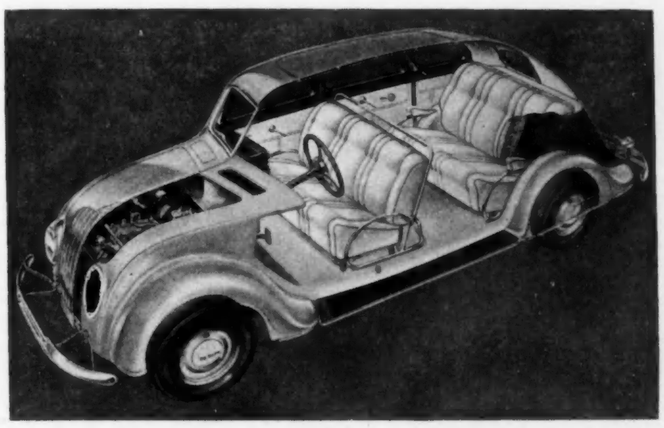
The Packard rear and rear quarter curtains are of the concealed type. Studebaker conceals the roller at the bottom. Graham uses a perforated type of rear curtain. The Ford door handles are raised for opening as a safety measure. A variety of materials and finishes are used for regulator handles and control knobs. Pontiac has Bakelite in walnut finish, Plymouth De Luxe onyx, Auburn Custom-8 Catalin, and Oldsmobile uses Tenite. Ash trays and hand grips are built into the Studebaker robe rail brackets.

Seats, Upholstery and Luggage Space

The extremely wide Chrysler doors have made one-piece front seats possible in the brougham and coupe models, although the seat backs are divided to permit folding. The Packard front seats are higher than formerly and carry softer cushion springs at the top. The seat backs have been orthopedically designed.

Packard has reverted to the wide-pleat type of upholstery from the plain trim. Narrow pleats are incorporated in the Pontiac and Oldsmobile. The Buick front compartment mats, cowl trimming, pedal pads and fittings all harmonize in color. The Ford and Packard headlining is trimmed to give a cove effect.

The DeSoto and Chrysler front seat accommodates three passengers being 50 in. wide. The seats are similar to modernistic chairs supported on chromium tubing which extends back of the front seat top and eliminates the need of assist cords. The rear seat arm rest is mounted on the tube. The DeSoto upholstery is frieze material which makes its first inception for automobile use. The Chrysler seats and



De Soto "airflow" model wtih modernistic seats and large luggage space in tail of body

interiors are fashioned in Bedford cord, piped with genuine leather.

Goodyear has developed rubberized hair for seat cushions and is used by Twin Coach. The cushion is graduated in stiffness from the bottom up to a very soft layer. The cushion will not bottom nor rebound as the coil spring type and saves 30 per cent in weight. Floor mats which have heretofore been black or dark grey are now being furnished by Goodyear in color.

Luggage space is provided behind the hinged back rear seat in the Dodge, Chrysler, DeSoto and Auburn. The Oldsmobile trunks are an integral part of the phaeton models. A heavy sponge rubber welt seals the seam of the Studebaker trunk.

Bus and Truck Fields

The Marmon-Herrington bus for use over the Syrian Desert is a notable development. The six-wheel drive tractor and two-axle semi-trailer is propelled by the Hercules Diesel and is capable of a speed of 60 m.p.h. The unit weighs 46,000 lb. and takes care of a 15,000 lb. load including 31 passengers and baggage. The Bender body has 2-passenger and 2-baggage compartments, complete buffet with icebox, sink and stove and a toilet compartment.

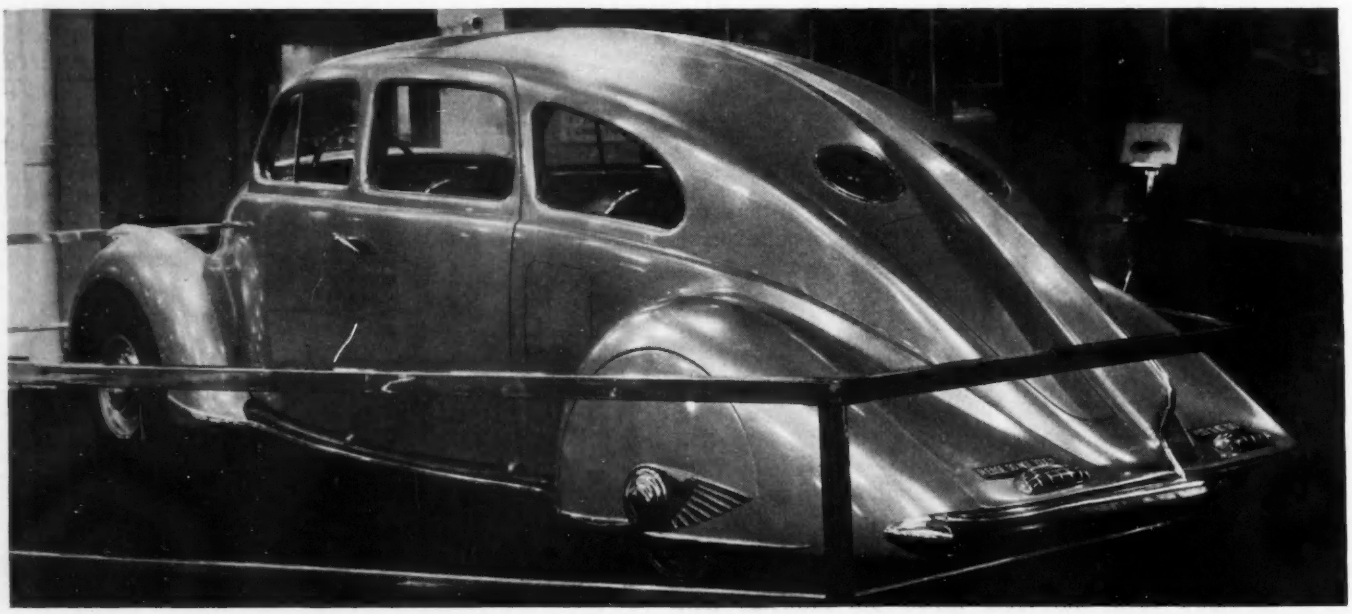
The A.C.F. Metropolitan Coach, model H-9, uses the Hall-Scott 6-cylinder 5 x 6 in. horizontal engine of 21 in. vertical height. The cylinders are on the left side to take advantage of the crown of the road to raise the "top end" of the cylinders and shift the center of gravity to the high side. The engine is self-contained except the cooling fan drive from the front end compressor. The crankcase and block are integral and each cylinder sleeve is in a separate compartment of the block, providing equal cooling and rigidity.

Sloping radiators, skirted fenders, V-windshields and well-rounded roofs have been incorporated in truck design. Legislation restricting overall length coupled with the desire for 1/3—2/3 weight distribution on the axles has resulted in the camel-back construction. This was pioneered by Autocar in which the engine is located under the seat. Circulation of air in the engine compartment is obtained by two ducts under and near the front of the truck. The air escapes through a louvred rear cover. Sterling and General Motors place the engine directly behind the radiator as in regular design. In the Sterling a through draft of air from the radiator is discharged through a screen at the rear of the cab. The windshield follows the same V-line as the radiator. In the G.M. the back of the engine compartment inclines to the floor with the gear shift lever rising in this space. With a chain block attached to the powerplant sub-frame at the front, the unit can be slipped forward on rollers attached to the rear.

The Texas Co. has built a tank truck with the engine located in the rear tail and the cab at the front in an unobstructed position. The frame has a front drop to support the cab and rises over the rear axle behind which the powerplant is suspended. Westinghouse air controls are used throughout. This design is a most distinctive development and heralds a breaking away from past traditions.

Brockway has developed a line of electric trucks in which the major units are identical with their gasoline driven models. The batteries are suspended at each side of the frame behind the front-mounted cab.

Rail cars are making rapid progress through the incorporation of such automotive developments as streamlining, light alloys, heat treated alloy steels and automobile engines. The Stout railplane is an admirable example in this direction. Budd's "shot-welded" stainless steel used in cars and trains as well as commercial bodies has also opened up possibilities in weight saving.



The product of Briggs Manufacturing Co. designers, this streamlined, rear-engined design is *not* in production by any car manufacturer. It has been displayed at the Ford Exposition of Progress in Detroit and New York.

Engine-Cylinder Flame-Propagation Studied by New Methods

By Dr. Kurt Schnauffer
German Institute for Aeronautical Research, Berlin

DR. SCHNAUFFER presents in this paper the results of research on and measurements of combustion processes in internal-combustion engines by means of a slow-motion camera and a micro-chronometer. This method for flame-propagation indication depends on the physical property of flame to ionize air gaps and hence make them conductors of electric current. The recording equipment used is very simple, he says, and can be simplified still further if only visual inspection of the combustion processes is desired. He gives also a brief review of the history of combustion-process research, and a bibliography.

Using this method, all the conditions affecting the speed of flame-propagation in a high-speed spark-ignition engine were examined, and Dr. Schnauffer emphasizes that the results were accurate.

Neon lamps can be substituted for an oscillograph, if desired, and are less expensive; further, this makes possible the registration of an unlimited number of test points. An aviation-engine cylinder was investigated by inserting 24 measuring gaps distributed over the entire surface of the combustion chamber, and neon lamps were used. This set-up represented a cross-section of the combustion chamber on which, as the lamps were lighted, the course of flame-front travel could be followed. Dr. Schnauffer points out that this method should be of special interest to universities as a means of instructing students.

THE efforts of various research workers have been directed for a long time toward the examination of combustion processes in fuel-air mixtures. While they confined themselves at first, due to the manifold difficulties of the problem, to fundamental research using combustion bombs and vessels, in recent years they have proceeded to investigate and to explain combustion processes directly in an engine in operation. This applies most particularly to the spark-ignition engine, the state of development and the uniformity of combustion processes of which made it a feasible field for investigation.

Proceeding from a single ignition point, the flame spreads over the entire combustion chamber. This flame spread as it takes place in bombs can be clearly seen in the works of Stevens[1], Maxwell and Wheeler[1] and Lindner[1]. In illustrations of flame travel in bombs, the rapidity with which the flame front advances can be seen clearly from the steepness of the boundary line of the flame; in other words, the increase in flame area.

Along with purely photographic recording, electrical means of indicating flame spread have been used. For instance, this was done in early years by Mallard and Le Chatelier[1], who discharged condensers by means of a flame; and by Terres[1], who brought thin lead or tinfoil to the melting point by means of a flame and thereby opened an electric circuit. Then the occurrence of detonation at high compression ratios instigated further investigation, especially in the engine itself.

In forming a conception of combustion processes, the different factors influencing flame-front movement in a closed vessel must be kept in mind. For instance, the flame, along with combustion speed which depends for the most part on the accompanying turbulence of the fuel-air mixture, is accelerated or retarded particularly by the speed of displacement due to local temperature rises. Endres[1] and Janeway[1] have explained so clearly the conditions entering into the situation that they are accepted universally. It appears that with a very low initial combustion-speed a relatively high positive expansion-speed may be associated and with a later high combustion-speed, a low negative expansion-speed; so that on the

[This paper was presented at the S. A. E. International Automotive Engineering Congress, Chicago, Sept. 4, 1933.]

[1] See the Bibliography at the end of this paper.

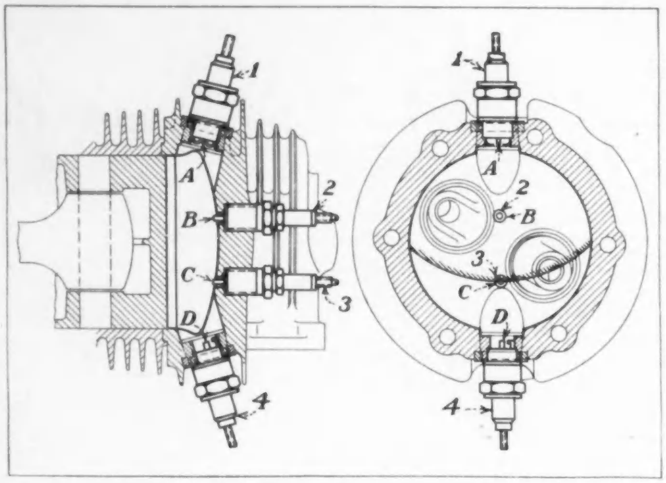


Fig. 1.—Flame-Spread Indication by Means of Ionization Currents

The combustion chamber is provided with spark plug 1, and measuring electrodes or ionization gaps 2, 3 and 4. The ignition current at *A* and the ionization currents at *B*, *C* and *D*, set up by the arrival of the flame at these points, are recorded by an oscillograph

average the speeds of flame-front travel in a combustion chamber are relatively uniform considering the entire course of combustion.

Determinations made on high-speed engines also have been published recently, particularly the work of Glyde[1], Withrow and Boyd[1], MacKenzie and Honaman[1], Marvin and Best[1] and the German Institute for Aeronautical Research[1] (Deutsche Versuchsanstalt für Lüftfahrt). While Glyde and Marvin and Best carried out stroboscopic observations of flame travel through small quartz windows and recorded them from visual inspection, Withrow and Boyd used a photographic method and MacKenzie and Honaman and the German Institute for Aeronautical Research an electrical measuring method. In this connection, attention should be called to the circumstance that Withrow and Boyd jointly and the German Institute for Aeronautical Research, at the same time and independently of each other, succeeded in explaining the physical processes and mechanical effects attendant upon detonation by means of records of flame movement and simultaneous pressures.

Ionization Current Indicates Flame Travel

The basis of the method developed in the German Institute for Aeronautical Research for flame indication is this; it depends on the physical property of flame to ionize air gaps and hence make them conductors of electric current. If a measuring unit or ionization gap containing two electrodes is inserted in a combustion chamber, and an electrical potential imposed on these electrodes, then current starts to flow between the electrodes at the instant that a flame reaches them. This current, after it has been amplified, can record its existence by deflecting an oscillograph beam or by means of any other inertia-free indicating apparatus. The method is practically inertia-free. The presence of a flame in a combustion chamber is shown in this way, for example, on an oscillograph record.

If a clear picture of combustion processes or a determination of the speed of flame propagation is the object of the investigation, then several of such ionization gaps or test points must be used, somewhat as shown in Fig. 1. The flame proceeds from ignition point *A* through the measuring gap *B* and *C* to the measuring gap *D*. From the oscillogram of Fig. 2, the time taken by the flame to traverse the different measuring zones may be seen. The deflection of the upper beam at *A* marks the beginning of the flame spread at the ignition point; those at *B, C* and *D*, the arrival of the flame at the respective measuring gaps. All these records are accompanied by the time record of a calibrated tuning fork shown as the bottom line of the oscillogram.

The German Institute for Aeronautical Research has in this way accurately examined all the conditions affecting the speed of flame propagation in a high-speed spark-ignition engine, as has been recorded in a previous, 1932, publication[1]. The values obtained in this investigation, along with a limiting value obtained by Neumann in a closed spherical bomb with no turbulence, are represented schematically in Fig. 3. It illustrates the intimate relations between combustion velocity, mixture ratio and turbulence. (The average velocity of the entering charge at the intake valve was chosen as a unit of reference by which to express the degree of turbulence.) Fig. 4 shows, as is already widely known, that turbulence in the fuel-air mixture plays the largest part in the combustion rate of a fuel. Mean combustion velocity is seen here to increase very nearly linearly with increased intake velocity. The mixture ratio also has considerable effect, while compression

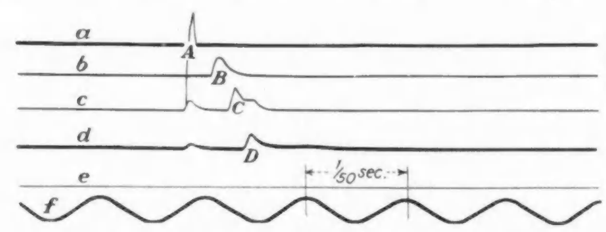


Fig. 2.—Oscillograph Record of Flame Spread

The deflection at point *A* marks the moment of ignition; those at points *B*, *C* and *D*, the arrival of the flame at the respectively lettered ionization gaps of Fig. 1. The bottom line is the time record of a calibrated tuning fork.

ratio as well as the type of fuel affect the speed only to an inconsiderable extent.

Registration of combustion speeds also makes possible an insight into detonation phenomena in an engine, as has been mentioned. Figs. 5 and 6 are oscillograms taken under conditions of detonating combustion. The lower sections of these oscillograms show that in detonation a certain part of the fuel commences to burn simultaneously, since evidently the flame arrives at points *C* and *D* at the same time. In Fig. 6

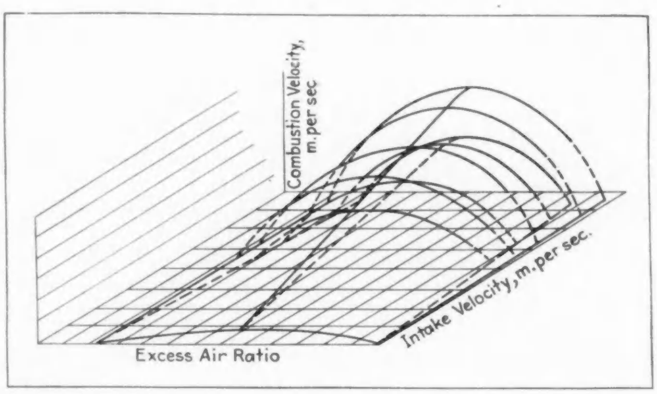


Fig. 3.—Relation between Combustion Velocity, Mixture Room and Turbulence

The values represented are those obtained in an investigation by the German Institute for Aeronautical Research, along with a limiting value obtained by Neumann in a closed spherical bomb with no turbulence

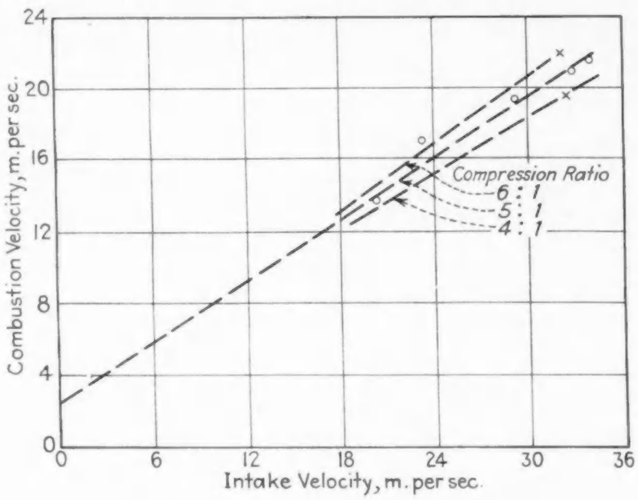


Fig. 4.—Relation between Combustion Velocity and Turbulence

Values obtained by the German Institute for Aeronautical Research. The average velocity of the entering charge at the intake valve is the unit of reference for expressing the degree of turbulence

may also be seen the simultaneous record of cylinder pressure made with an electric indicator developed in the German Institute for Aeronautical Research. Fig. 6 shows also the simultaneous arrival of the flame at the two last test points and the pressure rise due to the rapid combustion.

The recording equipment used in all these measurements of flame-front speed, with the exception of the oscillograph, is pictured in Fig. 7. It is very simple and can be simplified still further if only visual inspection of the combustion processes is used. As can be seen from the illustration, it consists of one R.E. 134 radio tube, a 4-volt filament battery, a 200-volt anode battery, a resistance of about 40,000 ohms, and a measuring electrode (spark plug). The wiring arrangement finally used consists of the simplified connections for direct current shown in Fig. 8. It was a development from two previous layouts, one for alternating current and one a more elaborate direct-current arrangement.

Neon Lamps Substituted for the Oscillograph

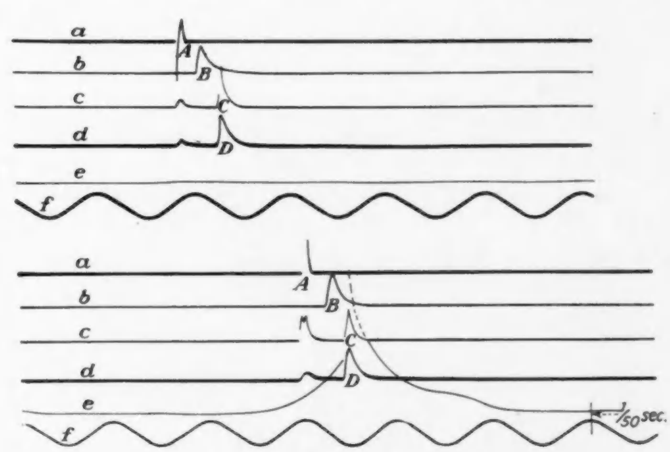
The disadvantages of a method requiring the use of an oscillograph are that such expensive recording apparatus is not everywhere available and that no more than six test points, corresponding to the six oscillograph elements, can be registered at one time. The limitation of the number of test points to six is a hindrance particularly in investigations of entire combustion chambers, as is indicated in the work of Marvin and Best, who used 32 test points[1]. The German Institute for Aeronautical Research therefore modified the method above described that was used in the earlier investigations by substituting special neon lamps for oscillograph elements as the means for indicating the arrival of the flame at the ionization gaps. This modification makes possible the registration of an unlimited number of test points. The electrical current which, as has been said above, is caused to flow at the instant of flame arrival at an ionization gap does not deflect an oscillograph beam but lights up a neon lamp. By the earlier or later illumination of the different lamps the course of flame travel in the combustion chamber can be followed.

Using the new method, the German Institute for Aeronautical Research has investigated a cylinder of an SH13 aviation engine by inserting in it 24 measuring gaps distributed over the entire surface of the combustion chamber, as shown in Fig. 9. In this test set-up the spark plugs formerly used as measuring gaps had to be replaced by measuring gaps of smaller dimensions, in the first place to make possible the introduction of a sufficient number of test units into the cylinder head and, in the second place, to reduce disturbance to the heat flow in the cylinder head to the smallest possible amount.

To obtain a good comprehensive view of the entire combustion process, all the lamps corresponding to the individual measuring gaps were arranged on a board in locations corresponding to the locations of the respective measuring gaps in the combustion chamber. The illustration at the right in Fig. 10 shows the lamps so arranged corresponding to the test points. This set-up, as can well be seen, represents a true picture of the combustion chamber; in fact, practically a cross-section of the combustion chamber is obtained on which, as the lamps are lighted up, the course of flame-front travel can be followed. Proceeding from the ignition point, the flame front spreads successively through the combustion chamber, reaches successively the individual measuring gaps and successively causes the corresponding lamps to be lighted. Observation of these cylinder cross-section facsimiles through a stroboscope while the engine is running reveals the moment of ignition and the course of the flame front spreading from the ignition point. Clearly to be seen is the bending of the flame front due to various cooling effects; for instance, the different influences of inlet and exhaust valve, and, in a turbulent-type combustion-chamber, the effects of turbulence. To make clear the entire process a cross-section model of the cylinder is also provided, as shown at the left in Fig. 11. In this the pistons and valves are built in their proper locations and operated at crankshaft speed. From the piston and valve movements the observer can judge when ignition and, consequently, flame movement must take place. Emphasis should be laid on the especial interest of this method for instruction in universities, since a living picture of the entire process is obtained.

New Equipment for Modified Apparatus

Concerning the new equipment and methods involved in the use of the modified apparatus, both as a whole and as to



Figs. 5 and 6.—Oscillograms Taken During Detonating Combustion

The lower sections of these oscillograms show that in detonation a certain part of the fuel commences to burn simultaneously, since evidently the flame arrives at points C and D at the same time. In Fig. 6 may also be seen the simultaneous record of cylinder pressure

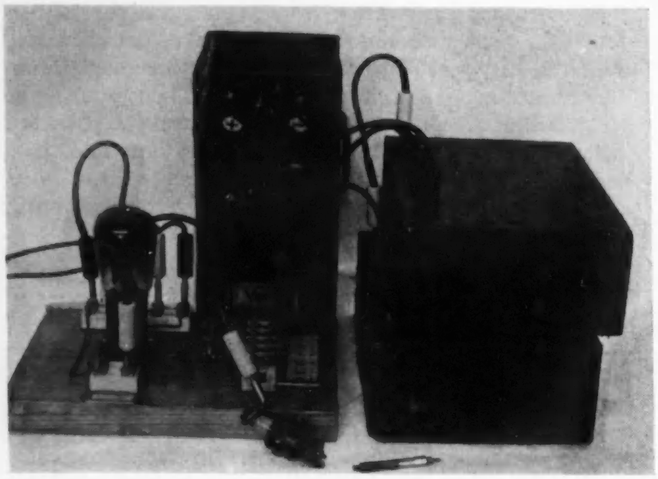


Fig. 7.—Equipment for Recording Flame-Front Propagation

It consists of one R.E. 134 radio tube, a 4-volt filament battery, a 200-volt anode battery, a resistance of about 40,000 ohms and a measuring electrode (spark plug).

individual details, the following may be said. Special units developed by Robert Bosch are used as measuring gaps. These measuring gaps have an average electrode diameter of from 2 to 2.5 mm. and require a special drilling in the cylinder head of only 3-mm. diameter. These units must be specially well insulated, since inadequate insulation may entail current leaks of the same order of magnitude as the ionization current, which is naturally not permissible. With regard to the neon lamps, considerable difficulties had to be overcome before an inertia-free lamp of high candlepower could be developed.

To complete the apparatus, a simple, easily handled amplifier and selector-distributor apparatus had to be developed. Although amplifiers are needed for each ionization gap, the amplifying apparatus which suffices for 24 test points and for the registration of two ignition points has proved to be relatively small because of the very simple repeater system.

The generator, which can be connected to an alternating or three-phase circuit, delivers the anode, grid and filament voltage needed for the entire apparatus. In the size illustrated it would be adequate for about 100 test points. Since the anode voltage amounts to 400 volts, the equipment is so arranged for the sake of safety in operation that the current-carrying circuit can be removed only after the current has been turned off. All the apparatus has operated reliably.

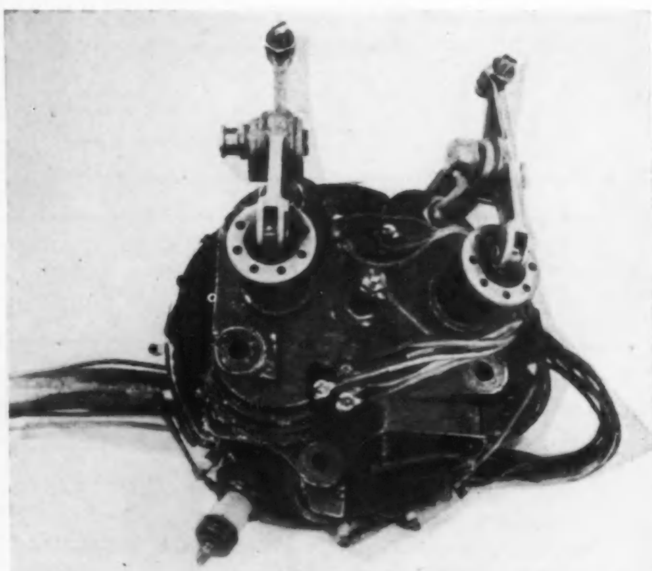


Fig. 9.—Cylinder of SH13 Aviation Engine

For the investigation of combustion phenomena in this cylinder, 24 ionization gaps were distributed over the entire surface of the combustion chamber

The equipment above described for transmitting and presenting for observation or registration the phenomena manifested at the combustion-chamber test-points by the setting up of electrical currents is shown in Fig. 11. At the left is the generator; in the center, the amplifying and selector-distributor apparatus and, at the right, the facsimile of the combustion-chamber and cylinder set-up for observation or registration.

Slow-Motion Camera Records Flame-Front Travel

Registration of the combustion processes shown by the neon lamps is obtained either by a slow-motion camera or by a micro-chronometer. The German Institute for Aeronautical

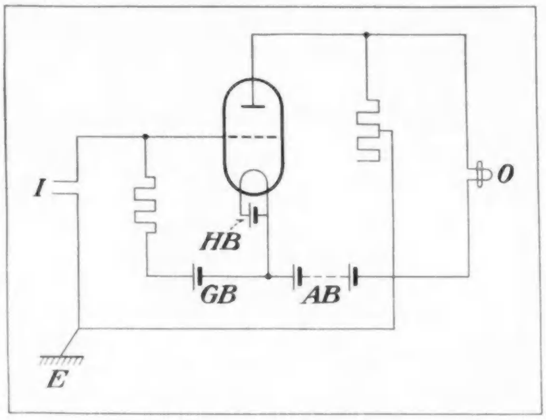


Fig. 8.—Wiring Diagram for Equipment Shown in Fig. 7

The letter *I* indicates the ionization gap; *E*, earth; *AB*, anode battery; *GB*, grid battery; *HB*, filament battery; and *O*, oscillograph

Research made its slow-motion pictures at the rate of 1500 per sec. As the film proceeds more and more lamps are seen to be lighted, according to the path taken by the flame front. From the frequency of the pictures and the distance of the measuring gaps from one another the rapidity of flame spread in the cylinder can be determined. As between a picture taken at an exposure frequency of 1500 per sec. and a film of the normal exposure rate of 16 per sec., there is a deceleration of 100 per cent. Through this means, the course of combustion in a cylinder can be represented and followed through on a screen. In addition to the facsimile of the combustion chamber, the cylinder cross-section model operated at crankshaft speed is also photographed. Mention should be made of the fact that the film so made is the first attempt to bring before a large audience, in this way, the processes taking place during combustion in a combustion chamber.

Diagrammatic Sketches Explain Film Data

Although this film is greatly slowed down, its speed is nevertheless relatively high, so that details, especially differences caused by various engine conditions, can be distinguished only with difficulty. Therefore the sketches incorporated in Figs. 12 to 18 were made. They are based on the data revealed by the film and show the course and rate of flame-front propagation. They represent the combustion-

chamber cross-section shown in Fig. 10, *E* being the inlet and *A* the exhaust valve and the separate points the locations of the neon lamps on the facsimile or the ionization gaps in the combustion chamber. The lines represent the flame front and the numbers its successive arrival at the various zones, the number 1, of course, representing the ignition point. The engine speed, ignition location and throttle opening prevailing during each of the seven runs filmed are indicated on each of the seven corresponding sketches.

Fig. 12 shows clearly the acceleration of flame propagation because of the large exhaust valve and the twisting of the flame front toward the right side of the combustion chamber caused by it. As can be seen, the flame front does not assume a strictly spherical shape.

In Fig. 13, representing a run made at half throttle and with a much lower exhaust-valve temperature, the influence of the exhaust valve, here almost wholly annulled through the cooling of the cylinders from the upper left side, is no longer seen. The flame front spreads in an almost circular form from one side of the cylinder to the other.

Fig. 14, on the other hand, taken with the engine idling, brings out the cooling effect which here by far outweighs the effect of the exhaust valve, in that the cooling proceeding from the upper left side causes the whole flame front to turn toward the left. Moreover, this figure shows that, in idling, turbulence disturbs the even form of the flame front.

In Fig. 15, ignition is shown to have taken place at the center. It is well adapted to show the preference given the exhaust side. Contrary to expectation, the influence of the exhaust valve is so strong that that of the cooling, proceeding from the upper left side, almost disappears. The number of circles inscribed shows that in central ignition, as might be expected, combustion results most quickly. In this connection, the rate of flame-front spread immediately after ignition, much higher than in side ignition (see the first four or five zones pictured), is of especial interest.

Fig. 16 pictures a case in which ignition was from the far side of the cylinder. The form of the flame front is very symmetrical, since the influence of the exhaust valve does

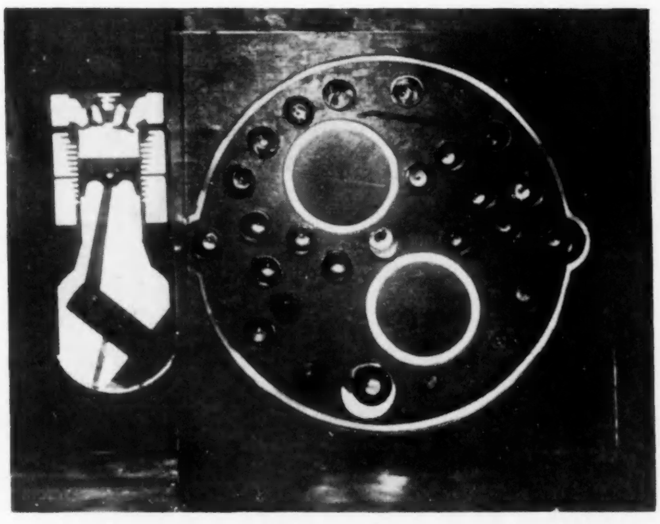


Fig. 10.—Equipment Used in Observation of Combustion Processes

At the right is a facsimile of the combustion chamber investigated, on which neon lamps are arranged in locations corresponding to the locations of the ionization gaps in the combustion chamber. At the left is a model of the cylinder cross-section, showing the piston and the valves, which are operated at crankshaft speed during the observations of flame spread as shown by the lighting of the neon lamps

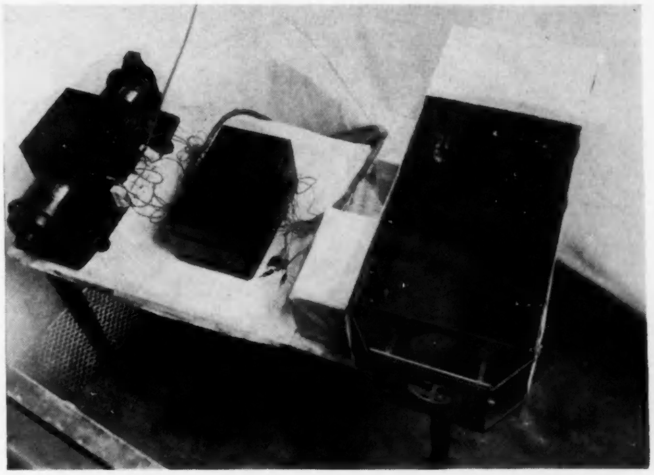


Fig. 11.—Modified Recording Outfit

At the left is the generator, which supplies the anode, grid and filament current; at the center, the apparatus for amplifying the current set up at the ionization gaps in the combustion chamber so that it can illuminate the corresponding neon lamps in the combustion-chamber facsimile at the right. At the left of the combustion-chamber facsimile is the model of the cylinder cross-section

not make its appearance until late; that is, after a high speed has been reached. The side of the cylinder remote from the cooling side, according to this illustration, is of equal influence with the exhaust valve so far as preparation of the fuel is concerned.

Concerning ignition near the exhaust or inlet valve, it may be said in general that ignition near the exhaust valve decreases the detonation tendency as well as the combustion speed, while ignition near the inlet valve increases both effects.

Fig. 17, which shows flame-front propagation with two ignition points, is self-explanatory. Fig. 18 reveals conditions existing in an engine during detonation. The almost simultaneous ignition of a large part of the mixture can be clearly seen. Only in the narrow neck, marked 10, has simultaneous ignition failed to take place.

This method of slow-motion-film recording serves to bring before a large audience the combustion processes taking place in a combustion chamber. If purely scientific determinations are desired, and that is the principal object of the investigation, then the accuracy achieved in such a record is no longer adequate. For even the slow-motion camera shows the lighting of the lamps only with an exactitude of 1/1500 sec.

Micro-Chronometer Developed for Scientific Accuracy

For more accurate measurements, the German Institute for Aeronautical Research has developed a micro-chronometer to register the illumination of the lamps. Several views of this apparatus are shown in Figs. 19 to 22. With this device as many as 24 lamps were recorded on a rotating highly sensitive registering paper. In order that several working cycles may be registered on a strip, the lamps are slowly pushed sideways. The entire apparatus is wholly automatic and its accuracy is very great.

To test the accuracy of the apparatus, a lamp was operated by means of a small transmitter with a frequency of 120,000 per sec. The running speed of the registering paper was 70 m. (229.66 ft.) per sec. As Fig. 23 shows, all the light points may be seen clearly and distinctly. The special neon lamps have operated reliably without once getting out of order. Moreover, an illumination period of 1/250,000 sec. for a

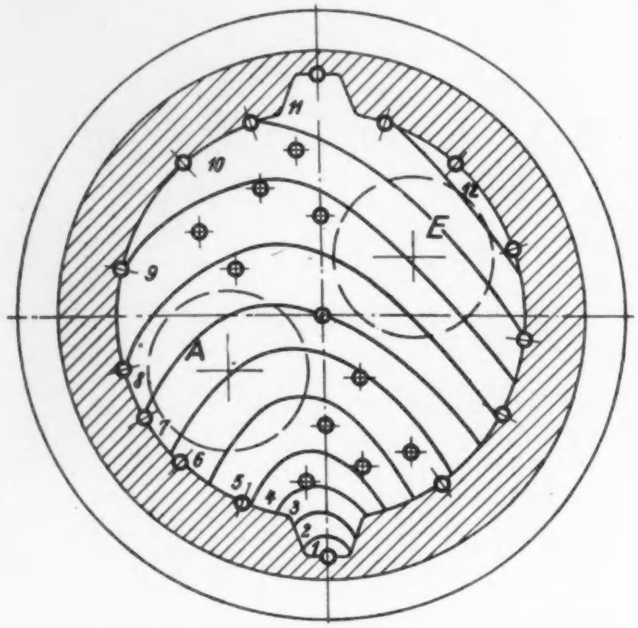


Fig. 12.—Speed, 1650 r.p.m.; ignition at the near side of combustion chamber; full throttle

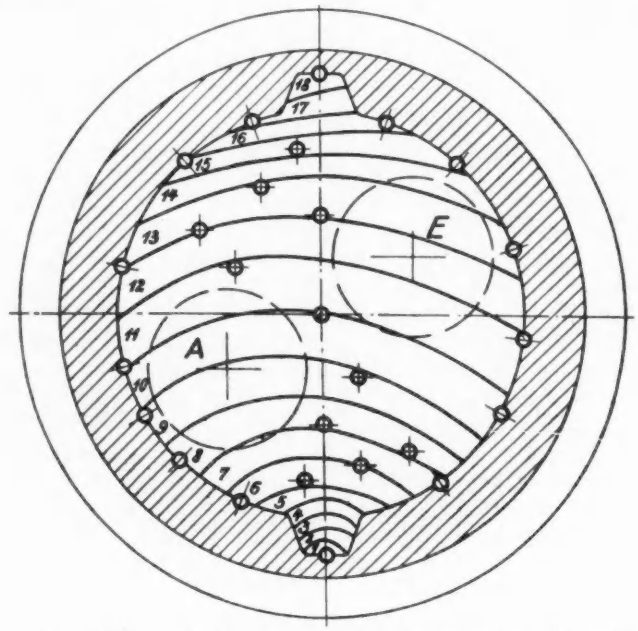


Fig. 13.—Speed 1000 r.p.m.; ignition at the near side of the combustion chamber; half throttle

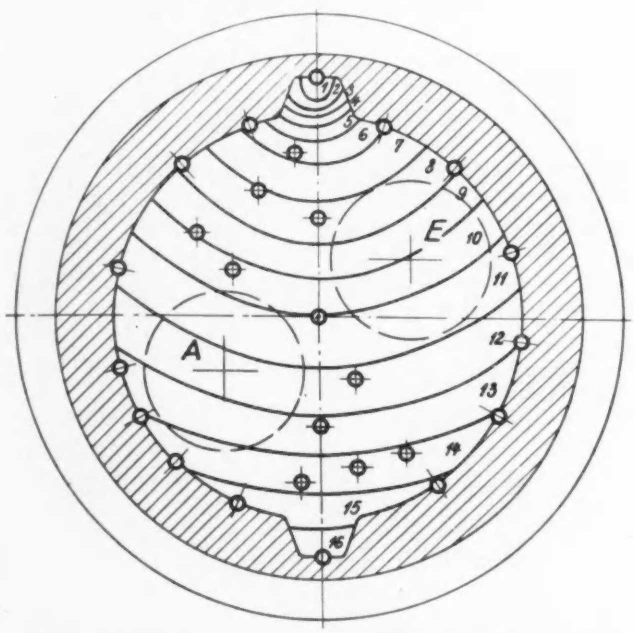


Fig. 16.—Speed, 1000 r.p.m.; ignition at far side of combustion chamber; full throttle

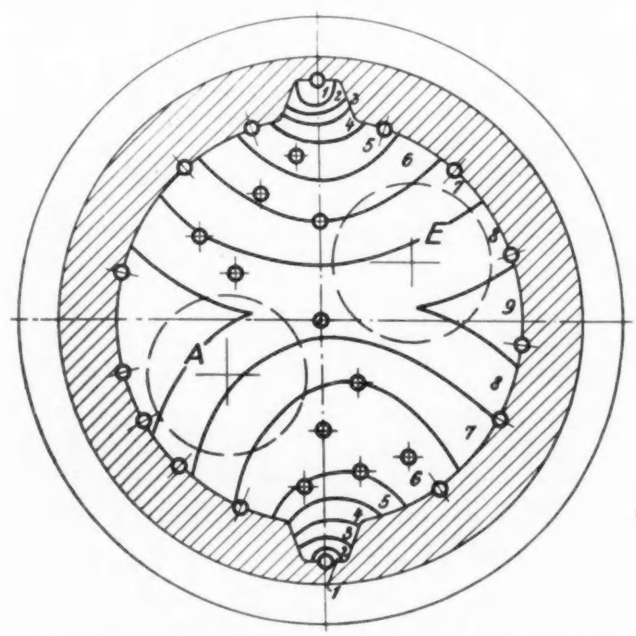


Fig. 17.—Speed, 1000 r.p.m.; double ignition; full throttle

point has succeeded in fully blackening the paper. Time differences of 1/250,000 sec. can therefore be accurately registered. The measuring possibilities of the neon lamps are of a somewhat higher order.

Measurements of the speed of flame-front propagation during knocking in an engine, carried out with this apparatus, gave speeds of 265 to 300 m. (869.42 and 984.25 ft.). In spite of very heavy detonation, no greater speed was observed. Hitherto published values of 2000 m. (6561.66 ft.) and more per sec. for flame-front-propagation speed during detonation, which for the most part were ascertained in tubes, do not seem to represent the true state of affairs. The speed lies well below the speed of sound.

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Fig. 14.—Speed, 400 r.p.m.; ignition at the near side of the combustion chamber; idling

Fig. 15.—Speed, 1000 r.p.m.; central ignition; full throttle

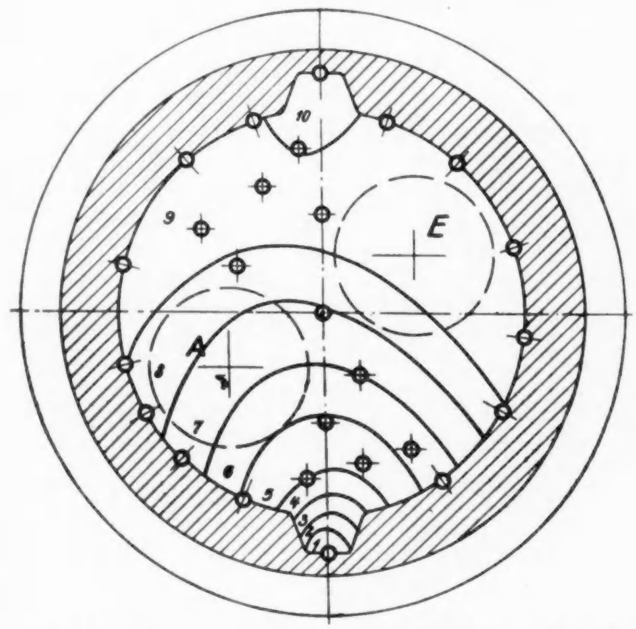

Fig. 18.—Speed, 800 r.p.m.; ignition at near side of combustion chamber; full throttle

Course and Rate of Flame Propagation

These diagrammatic sketches are based on the slow-motion picture of the combustion-chamber facsimile in which the neon lamps are operated by the ionization current, the points representing the ignition point and the 24 ionization gaps and the numbers designating the successive zones of flame propagation. The letter *E* indicates the inlet, and *A* the exhaust valve. The engine conditions prevailing in each of the runs are as shown in Figs. 12 to 18.

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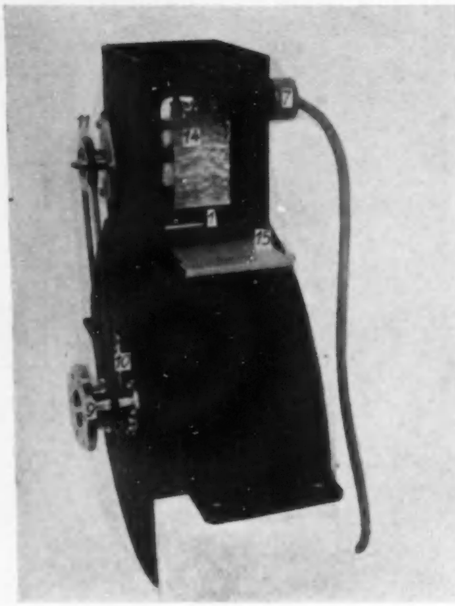

Fig. 19

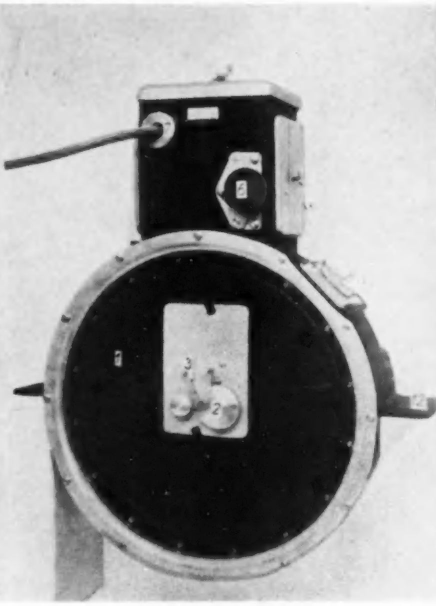

Fig. 20

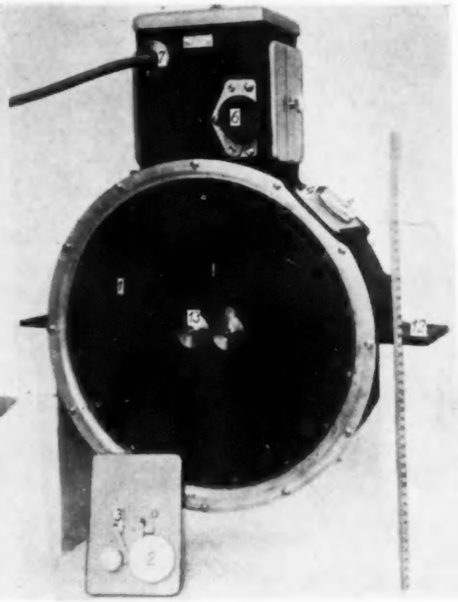

Fig. 21

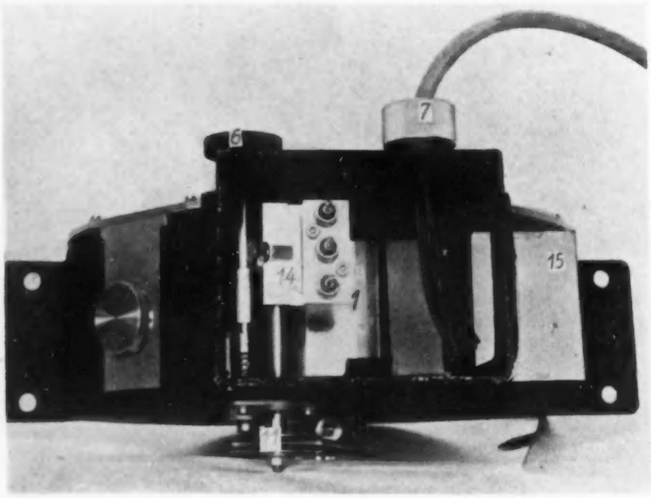

Fig. 22

Figs. 19 to 22—Michronometer for Recording Combustion Velocity with Scientific Accuracy

As many as 24 lamps were registered on a rotating highly sensitive registering paper. Time differences of 1/250,000 second can be accurately registered with the apparatus

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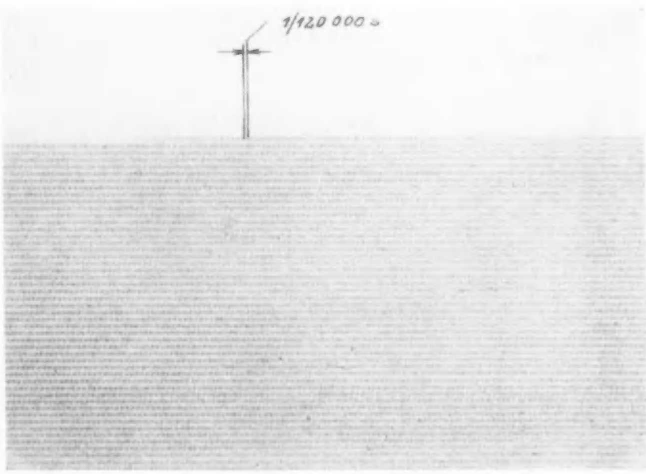

Fig. 23—Sample Michronometer Record

This record was made from the operation of a lamp at a frequency of 120,000 per sec., the running speed of the registering paper being 70 m. (229.66 ft.) per sec.

Effect Shown of Variable Charges on Fleet-Operation Economy

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OPERATING, or so-called variable charges, are considered in this paper, and comments are offered on the subject of fixed charges.

Because economies effected since about 1929 have brought fleet-operation costs to a very low level, the difficult problem of how they can be further reduced and yet maintain the same quality of service is facing all fleet operators; but it is not insurmountable. Through adequate study of each item of operating expense, and with proper treatment of each item of cost, Mr. Newton believes that reductions will be effected.

Itemizing the charges, Mr. Newton says that gasoline purchase is primarily the buying of heat units. Gasoline should not deteriorate in storage, must be clean, have low sulphur content and should not vapor lock. Using a higher antiknock gasoline than necessary increases fuel cost. Correct and effective lubrication lengthens vehicle life and reduces repair costs; as few different grades as will assure good lubrication should be used.

Mr. Newton advocates periodic inspections, preventive maintenance, engine governors, air cleaners and oil reclaiming, as well as other basic practices. He analyzes garage expenses, and prefers vehicle-depreciation on a time-and-mileage basis. "Save-A-Mile" and accident-prevention campaigns have reduced costs in fleets that he cites.

THRIFTY administration is synonymous with economy. It implies doing the same amount of useful work for less money with no impairment of the quality of the work done or service rendered. Anyone can lower transportation costs temporarily by arbitrarily reducing wages, eliminating personnel, deferring maintenance, discontinuing essential services or buying supplies on a price rather than a performance basis, but certainly this is not thrifty administration, and is therefore not economy.

In most well-managed fleets of motor vehicles, the cost of operation has declined sharply during the last three or four years. The chief reasons for this are better management, better selection of vehicles, lower commodity prices, improved chassis and bodies, reduction in weight and size of bodies and chassis employed, and improved commodities allied with the motor vehicle; such as gasoline, oil, tires, brake lining, storage batteries and spark plugs. Further, driver education and accident-prevention work, improved maintenance methods including inspection and preventive-maintenance plans, employment and the use of good accounting practices.

How transportation costs can be reduced to still lower levels and yet maintain the same quality of service now being rendered is the problem facing all fleet operators regardless of whether the motor vehicles are passenger cars, trucks, or buses. The job is difficult, especially because retrenchments and economies already effected have brought costs to a very low level. We have been or are now facing increased commodity prices, higher wages and increased taxes, and none of these are conducive to lower costs. But the problem is not insurmountable.

It is believed that, through adequate study of each item of expense and with proper treatment of each item of cost, reductions will be effected.

The items of expense which comprise the total cost of operating motor vehicles are as follows:

- Operating or Variable Charges
  - Gasoline
  - Oil
  - Tire Renewals and Repairs
  - Repair Material
  - Repair Labor
  - Repainting, Labor and Material
  - Accident Expense, Labor and Material
  - Garage Expense, Such as Washing and Greasing
- Fixed Charges
  - Rent
  - Insurance
  - License and Taxes
  - Interest
  - Depreciation Reserve
  - General Expense

The operating or so-called variable charges are considered in this paper, although brief comments are offered on the subject of fixed charges.

Gasoline

Gasoline, or fuel, is one of the items which the fleet operator may well study. The selection of the proper grade of gasoline, the condition of the equipment in which it is consumed the nature of the equipment and the conditions under which it is operated all play an important part in determining fuel cost per mile. It will only be possible herein to point out some of the considerations in the selection of gasoline and their significance in service.

The purchase of gasoline is primarily the buying of heat units. All gasolines are hydrocarbons and have substantially the same heat value, the differences which do exist being almost within the experimental area. Potentially, 1 lb. of a given gasoline contains almost the same amount of energy as another, but certain of its properties vary and are significant from an economy standpoint and these will be treated briefly.

Gasoline should not deteriorate in storage. This is especially important to the fleet operator who buys gasoline in tank-car or tank-wagon lots. The most important result of deterioration or unstability is gum formation. Gum will deposit in the fuel lines, carburetor and manifold, and cause sticking valves, all resulting in considerable difficulty, time-loss and expense. In unstable gasolines, as gum forms the knock rating declines.

Water and dirt in gasoline are a source of annoyance and expense to the operator and should be safeguarded against. Gasolines containing a high percentage of sulphur will cause difficulty, particularly in winter, as the sulphur during combustion becomes sulphur dioxide which, dissolved in water, forms dilute sulphurous acid that will etch piston pins, bearings and timing gears.

Another point to consider is the vapor-locking tendencies of the fuel. Reid vapor pressure is used to determine the vapor-locking characteristics, and winter gasolines have higher Reid vapor pressures than those used in summer. This is necessary to secure satisfactory starting and flexible performance of the engine in cold weather. Trouble due to vapor lock usually arises during the summer and in most cases it is desirable to insulate or re-locate the fuel line rather than to attempt to purchase fuels having low Reid vapor pressure. The location of the fuel pump is also of importance, and certain motor-vehicle manufacturers might improve their vehicles by re-locating the fuel pump to cool it more effectively. It may be well to point out that many cases of trouble which have been diagnosed as vapor lock have been corrected by cleaning the sediment bowl or gasoline strainer, or tightening the gasoline strainer to stop leakage.

Regarding the A. S. T. M. distillation curve, the 10 and the 90-per cent points are the most important. The 10-per cent point gives indication as to the gasoline starting-characteristics in cold weather, its distribution characteristics and vapor-locking tendencies. The 90-per cent point gives further indication of the distribution characteristics and completeness with which it will burn. This is important not only from a power output, but also from a crankcase-dilution standpoint.

During a recent extensive motor trip through 16 states in the Southwest, West and Northwest, I experienced a variation in temperatures of from approximately 40 to 130 deg. fahr. and a difference in altitude from sea level to 14,000 ft. The thought came to me that, to serve a given area best, the

Table 1—Results of Tests on 188 Cars with Engelhard Air-Fuel Ratio Analyzer

	As Found				Corrected to Satisfactory Ratio by:								
Make and Type	Tested	No. O.K.	No. Rich	No. Lean	Carburetor Adjusted	Carburetor Repaired or Changed	Jets Changed	Cleaned and Set Breaker Points	Timing Corrected	Cleaned and Reset or Replaced Plugs	Valves	Misc.	Total Adjusted
Ford Passenger Cars	71	22	49	—	19	16	11	17	3	23	1	—	90
Ford ½-Ton Trucks	42	14	24	4	10	6	6	8	3	9	—	—	42
Ford 1½-Ton Trucks	21	7	11	3	6	4	3	3	—	2	—	—	18
GMC 1 Ton	17	5	11	1	11	—	—	2	1	2	—	1	17
GMC 1½ Ton	14	9	5	—	4	—	—	1	—	1	—	—	6
GMC 2 Ton	4	—	4	—	3	1	—	—	—	—	—	—	4
GMC 2½ Ton	1	1	—	—	—	—	—	—	—	—	—	—	—
Graham 2 Ton	1	—	1	—	1	—	—	1	—	—	—	—	2
Mack 2 Ton	5	4	1	—	—	1	—	—	—	—	—	—	1
Mack 3½ Ton	8	2	6	—	4	2	—	—	—	—	—	—	6
White 2½ Ton	3	3	—	—	—	—	—	—	—	—	—	—	—
Mack 5½ -Ton Crane	1	1	—	—	—	—	—	—	—	—	—	—	—
Total	188	68	112	8	58	30	20	32	7	37	1	1	186

Fig. 1—Slogans Used in "Save-A-Mile" Campaigns

gasoline refiners would have to know the operating characteristics of that area and build their gasoline accordingly. Some refiners do this within conservative limits and I believe are winning public acceptance of their products thereby.

Antiknock value in gasoline is of importance to the fleet or bus operator in that the price of the fuel is based to a degree on octane rating. Usually, the cheaper gasolines have a lower octane rating than do the more expensive. I have found it most economical to select a fuel with sufficiently high antiknock value to give the most satisfactory and economical operation in the majority of the equipment. One will save money by not using a better grade of gasoline than his fleet demands; on the other hand, one may increase his fuel and his maintenance costs by using too poor a grade of fuel. With proper selection it is possible to reduce gasoline consumption, particularly if it is necessary to enrich the mixture of gasoline and air or retard the spark to use gasoline with lower antiknock characteristics.

Generally speaking, it will increase the cost of fuel to use a higher antiknock gasoline than necessary unless at the same time the compression ratios are increased through engine modification. The increased horsepower obtained through higher compression ratio may make possible reduction in vehicle time on the road, in which case the reduced cost of drivers' and helpers' wages may offset increased fuel cost or result in a profit to the operator.

From an economy standpoint the foregoing properties should be considered by every fleet operator in making his fuel purchases, and his selection should be based upon satisfactory performance and economy in the majority of the fleet. My experience is that the large responsible refiners adhere very closely to given limits, changing these only because of seasonal demands. Such gasoline is therefore uniform and, while it may cost more per gallon than some fuels that might be purchased from unreliable sources, it is cheapest in the long run.

Recently, one of our companies has done considerable constructive work with an air-fuel ratio analyzer. Tables 1 to 3 show the results attained on tests of 188 vehicles. Table 1 shows that 68 vehicles, or 36 per cent, had a satisfactory air-fuel ratio; 112 vehicles, or 60 per cent, had unsatisfactory air-fuel ratios and corrections were necessary for economical fuel consumption; and 8 vehicles, or 4 per cent, had lean carburetor mixtures.

The work necessary on the vehicles in Table 1 to bring about satisfactory air-fuel ratios was that carburetors were adjusted on 58 vehicles; the carburetor was repaired or changed on 30 vehicles; the carburetor jets were changed in 20 vehicles; breaker points were cleaned or set in 32 vehicles; the timing was corrected in 7 vehicles; spark plugs were cleaned or reset or replaced in 37 vehicles; and valves were ground in 1 vehicle.

Table 2—Typical Air-Fuel Ratio Readings Before and After Making the Adjustments Shown on 20 Representative Vehicles

			Air-Fuel Ratio Found										Air-Fuel Ratio After Adjustment	
No.	Make	Type	Idle	Speed	Carburetor Adjusted	Carburetor Repaired or Replaced	Jet Changes	Cleaned and Set Breaker Points	Corrected Timing	Cleaned and Reset or Replaced Plugs	Valves	Misc.	Idle	Speed
273	Ford	A Coupe	12.9	10.7	—	—	—	x	—	—	x	—	12.9	13.0
482	Ford	A Sedan	10.0	11.0	—	x	—	—	—	—	—	—	13.0	13.0
252	Ford	A Sedan	11.0	10.8	—	x	—	x	—	x	—	—	13.7	13.0
37	Ford	B Coupe	11.5	10.0	—	—	—	x	—	x	—	—	13.0	12.7
595	Ford	A Coupe	13.2	11.0	—	—	x	x	—	x	—	—	13.2	13 2
211	Ford	A Sedan	11.5	10.5	—	x	—	—	x	x	—	—	12.7	13.0
190	Ford	B ½ Ton	11.0	12.0	—	—	—	x	—	x	—	—	12.8	13.0
159	Ford	A ½ Ton	9.0	12.0	x	—	—	x	—	—	—	—	12.7	12.8
283	Ford	A ½ Ton	10.0	10.6	—	—	x	—	—	x	—	—	13.0	12.7
452	Ford	AA 1½ Ton	12.0	11.2	—	—	x	x	—	x	—	—	13.1	13.4
229	Ford	AA 1½ Ton	12.0	12.4	x	—	—	—	—	—	—	—	13.2	12.4
62	Ford	AA 1½ Ton	12.7	10.4	—	—	x	—	—	—	—	—	13.2	12.8
351	GMC	T-19	10.0	11.0	x	—	—	—	x	—	—	—	13.0	13.3
349	GMC	T-19	11.3	11.5	x	—	—	—	—	—	—	—	13.0	12.8
134	GMC	T-30	12.4	10.2	x	—	—	—	—	—	—	—	13.0	12.5
129	GMC	T-26	11.5	11.0	—	—	—	x	—	x	—	—	12.8	12.7
493	Mack	AB-2 Ton	11.0	12.0	x	—	—	—	—	—	—	—	13.0	12.0
44	Mack	AC-3½ Ton	9.0	9.0	x	—	—	—	—	—	—	—	12.7	12.8
17	Mack	AC-3½ Ton	13.4	9.0	x	—	—	—	—	—	—	—	13.4	12.0
40	Mack	AC-3½ Ton	12.8	11.6	—	x	—	—	—	—	—	—	13.0	12.7

Table 2 shows typical air-fuel ratio readings before and after adjustments on 20 vehicles selected from all data gathered, these being believed representative. Table 3 shows the relation existing between air-fuel ratio and completeness of combustion.

We find that it takes from 15 to 45 min. to test and adjust individual vehicles, depending upon the conditions found and the amount of work necessary. As yet we have not determined the exact relation that exists between increased completeness of combustion and miles per gallon attained by the vehicle. On the few tests that have been made it would appear that increased 1-gal.-test miles-per-gal. has been from 30 to 50 per cent of the increased completeness of combustion. But it is our belief that the final result will show that this work is well justified and that the savings effected will be relatively large; further, performance of the vehicles will be higher.

Dragging brakes cause gasoline consumption. It was not until a few years ago, when we equipped most of our shops and garages with axle-type lifts to facilitate washing and greasing, that we discovered how many of our vehicles had dragging brakes. Freeing these brakes has saved hundreds of dollars in fuel cost, to say nothing of decreased wear of drums and brake lining.

Replacement of piston rings at proper intervals also reduces gasoline consumption. It is the practice in our companies to study the gasoline consumption of each vehicle each month and, when it is determined that engine condition is responsible for excessive gasoline consumption, necessary replacements of rings, reconditioning of valves or other necessary work is done.

The use of the proper grade of oil affects gasoline consumption materially. It is our aim to use as light an oil as possible (low S.A.E. No.), our thought being that in so doing we decrease internal friction in the engine. Our oil consumption may be slightly increased through this practice; however, the saving in fuel more than offsets this aspect of the question. Keeping the air cleaner clean is absolutely necessary. Mixtures are enriched through dirty air cleaners and gasoline waste results.

Governors limiting the speed of vehicles within reasonable limits will save fuel. In our companies the greater percentage of passenger cars and light commercial vehicles are governed at 45 m.p.h., light trucks at 35 m.p.h. and heavier trucks even at lower limits depending upon size, nature of tire equipment, location in which operated, state vehicle laws and city ordinances. Educational campaigns in which the importance of careful driving is impressed upon operators pay dividends in reduced gasoline consumption and maintenance expense.

The elimination of unnecessary use of vehicles has reduced the gasoline bill as well as the total cost of transportation in our companies. "Save-A-Mile" Campaigns were instituted whereby operators were asked to reduce their mileage through elimination of personal usage of vehicles, through better routing and through the eliminationof non-essential usage. The slogans used are shown in Fig. 1. This has resulted in material reductions in mileage and, apparently, there has been no impairment of their function.

Lubricants

Correct and effective lubrication of motor vehicles is an economic necessity. It is a matter worthy of careful study by all operators and is sure to return worthwhile dividends in the form of longer vehicle life, lower repair costs and lower total cost of operation.

In deciding upon the make and grade of oil and lubricants to use, full weight should be given to the complex character-

istics of the modern motor-vehicle engine and chassis. High and low speeds of rotating parts, tooth and bearing pressures, temperatures, ability to maintain lubrication seals, variable load, the intrusion of abrasives such as road dust or grit, are all encountered in the simplest car or truck.

For simplicity and economy of operation, the number of lubricants decided upon should be as few as will assure good lubrication, but the number should not be unduly restricted to the extent that lubrication of certain parts is not adequately and correctly accomplished.

In the selection of motor oils the recommendation of the manufacturer of the vehicle should be closely followed as regards viscosity or S.A.E. number. The oil of lowest viscosity which will effectively lubricate the engine should be used. Experience has shown that, for most automotive purposes, suitably refined oils of paraffin, naphthene or mixed base may be used with equal satisfaction. The most important factors in the selection of a good oil are the reliability, skill and ability of the refiners, and their adherence to uniformity rather than the type of crude used.

A much discussed question is how often oil should be changed. I do not believe that there is a simple answer to this question. If a good quality of oil is used, if operating temperatures of the engine are unfavorable to crankcase dilution, if climatic conditions are unfavorable to formation of water in the crankcase, and if the engine is equipped with an oil filter, then the periods between oil changes may be safely prolonged to possibly every 2500 to 3000 miles. The level of the oil in the crankcase must be checked and fresh oil added when necessary. Some operators believe that under these conditions it is not necessary to change oil at all except from summer to winter grade, and vice versa; however, as yet I cannot subscribe to this theory. I believe, however, that with the improvement and general use of oil filters and with water temperature controlled with a thermostat and with the further safeguard of adequate air cleaners on the carburetor air intake and on the breather, that the day will come when we will not change oil except to meet seasonal demands.

Table 3—Relation Between Air-Fuel Ratio and Completeness of Combustion

Air-Fuel Ratio	Completeness of Combustion, Per Cent	Air-Fuel Ratio	Completeness of Combustion, Per Cent	Air-Fuel Ratio	Completeness of Combustion, Per Cent
9.0	50.0	10.9	60.75	12.8	76.20
9.1	50.5	11.0	62.00	12.9	76.80
9.2	51.0	11.1	63.00	13.0	77.40
9.3	51.5	11.2	64.00	13.1	78.00
9.4	52.0	11.3	65.00	13.2	78.75
9.5	52.5	11.4	66.00	13.3	79.50
9.6	53.0	11.5	67.00	13.4	80.25
9.7	53.4	11.6	67.80	13.5	81.00
9.8	53.8	11.7	68.60	13.6	82.50
9.9	54.2	11.8	69.40	13.7	84.00
10.0	54.6	11.9	70.20	13.8	85.50
10.1	55.0	12.0	71.00	13.9	87.00
10.2	55.4	12.1	71.67	14.0	88.33
10.3	55.8	12.2	72.34	14.1	89.66
10.4	56.2	12.3	73.01	14.2	90.99
10.5	56.6	12.4	73.68	14.3	92.32
10.6	57.0	12.5	74.35	14.4	93.65
10.7	58.25	12.6	75.00	14.5	95.00
10.8	59.5	12.7	75.60	—	—

There appears to me to be a distinct need for an instrument that will readily indicate the viscosity and the contamination of oil in the engine crankcase, the readings of such an instrument being used as a means for determining the necessity for oil changes. While there are some instruments offered, as yet I have seen none that will answer all requirements.

If the fleet operator is reclaiming his oil, the period between oil changes can be reduced as the waste of throwing away good oil is eliminated. We have been reclaiming oil for the last five years, and our experience has been so universally satisfactory that we have come to consider properly reclaimed oil equal to new oil. The cost of motor oil per annum is considerably reduced through the use of an oil reclaimer. The percentage of recovery is from 50 to 75 per cent of the oil dispensed and the cost of reclamation, including all items of expense, is from 12 to 16 cents per gal. In one of our companies in the Southwest, operating some 100 passenger cars and trucks, the cost of reclamation last year was 12.2 cents per gal. It recovered 43 per cent of the oil it dispensed and effected a saving in its oil bill of approximately $400. A typical analysis of oil before and after reclaiming is as follows:

	Before Reclaiming	After Reclaiming
Gravity, A. P. I. deg.	25.5	24.8
Flash Point, deg. fahr.	210	390
Fire Point, deg. fahr.	420	465
Neutralization No.	0.18 (Acid)	0.04 (Alkali)
Carbon Residue, per cent	1.0	1.0
Ash, per cent	0.088	0.039
Viscosity, sec.; at, deg. fahr.:		
100	495	660
130	223	277
150	148	178
210	63	70

The present-day motor vehicle is a complex structure and requires more than one kind of lubricant. A small number of manufacturers of passenger cars and trucks employ a central or magazine type of oiling system, using motor oil as a lubricant for chassis parts such as spring shackles, king pins and steering connections. It is hoped that, as time goes on, more manufacturers will adopt this or a better system to lubricate chassis parts automatically. Even when this is done, specialized lubricants for such parts as steering gears, wheel bearings, water pump, universal joints, transmissions, hypoid gears and conventional rear axles will be necessary, and some of these must be furnished in summer and winter grades.

A few years ago, after a study of four parts replacement, we determined that much of the necessity for replacement was due to faulty lubrication and that specialized lubricants were necessary. The lubricants which we decided to employ were motor oil, transmission lubricant, high-pressure chassis-lubricant or 600W, water-pump grease, wheel-bearing grease, steering-gear lubricant, universal-joint grease, hypoid-gear lubricant and, in addition, shock-absorber fluid and penetrating oil.

Since we have utilized specialized lubricants, we have materially reduced the cost of repairs. Some of the items that stood out in particular are as follows. Before beginning the use of a good wheel-bearing lubricant, chassis lubricant or cup grease was used and we had a considerable number of

bearing failures. Today these have been practically eliminated. Before beginning the use of a good universal-joint grease, we had considerable universal joint wear, which has been reduced to a minimum. Water-pump-shaft failures have been reduced since the introduction of water-pump grease. Not only have replacements of shafts been lessened but cooling systems are much freer from oil and scum; hence, the expense of cleaning radiators and cooling systems has been very materially reduced. Steering-gear wear was quite high before we started using a real steering-gear lubricant. For chassis lubrication we have attained excellent results with 600W rather than high-pressure grease. Whether one is better than the other is a debatable question.

Just what the elapsed time between periodic greasings should be is difficult to answer as there are so many variables to consider. Some operators grease on a time basis, weekly or semi-monthly; others on a mileage basis, varying from 500 to 2500 miles. We attempt to follow the manufacturer's recommendations and have found that frequent lubrication is always desirable and that it is not economy to try to save money by stretching out the periods between greasings too far. Grease is cheaper than repair parts. We have also found that it is true economy to use only the best lubricants, as cheaper ones have always been expensive in the long run.

It is almost universally agreed that vehicles should be washed and chassis freed of accumulated mud and grease before lubrication. This facilitates the work of the greaser and precludes the possibility of abrasive grit being forced into the bearings. At the same time that vehicles are lubricated, shock-absorber fluid is checked and any lost by leakage is replenished. Penetrating oil or crankcase oil is used for spraying springs and oiling brake linkage.

Modern, well-designed lubrication-equipment is essential to dispense these various lubricants properly, and careful thought should be exercised in its selection. Electric and air-operated guns produce equally good results for chassis lubrication. The size of the gun for this work should be governed by the number of vehicles to be serviced, the 25-lb.-capacity gun being adequate in most cases. Scissors or level-type-guns or compressors of from 1 to 1½-lb. capacity are recommended for the lubrication of steering gears, wheel bearings and universal joints. A separate gun should be provided for each specialized lubricant.

To handle successfully the heavy grease for water pumps, a screw-type compressor with very heavy threads developing a high pressure, is most suitable. This need not be of greater capacity than 8 oz. as the amount of grease needed to lubricate a pump is very small. A suction-type gun for filling shock absorbers will prove its worth in providing an easy way to accomplish this job. The fluid is quite expensive, and spillage will be avoided if some such means is employed. Transmission and differential grease may be dispensed direct from the drum in which it is received by simply screwing a pump into the head. If this means is not used, a grease bucket should be used. A spray gun attached to the air line will prove indispensable in spraying springs. There are several good ones available in which the flow of atomized oil is adjustable to suit the requirements of the user.

The majority of the equipment just described can be conveniently arranged on a lubrication board which can be made portable by the addition of casters. There are many advantages in this arrangement, in that the board can be taken any place in the shop to do lubrication jobs and the mechanic will have everything at his finger tips. If a greasing bay is provided, portability of the board is not necessary. We have found in our larger garages that hydraulic lifts of the axle type are indispensable to facilitate greasing.

I would like to stress the point that the life of parts properly lubricated is indefinite, and that through proper lubrication we can come closer to getting the life out of these parts that the manufacturer has built into them.

Tires

Tire renewal and repair cost has been a low percentage of the total cost of operation in most fleets during the last two years, due to the low first cost of tires and to their excellence; however, the cost of tires is advancing, and we can expect still higher tire prices before very long. Some factors in tire usage can be controlled; namely, heat and slippage. If this is done, large economies will result.

Heat may be from some outside source or it may be generated by the tire itself, or the two sources may combine to render an extremely undesirable condition. Not only does the thread rubber of tires wear off much faster when hot, but also the rubber underneath the thread and between the plies becomes soft under its influence and results in separation. Once separation commences, it is hard to stop and the life of the tire is limited.

Overloading, causing undue flexing of the side walls, is one of the principal sources of heat. Trucks may be equipped with tires of sufficient carrying capacity to handle their rated loads, but statistics indicate that the average truck in actual service is considerably overloaded. Results of a recent survey by the U. S. Department of Commerce indicated the following:

Manufacturers' Rated Capacity, Tons	Average Excess of Rated Capacity of Truck, per U. S. Department of Commerce, Per Cent
1	62.2
1½	71.8
2	87.7
2½	93.9
3	68.8
3½	70.4
4	68.2
5	42.9
5½[a]	7.6[b]

[a]And over. [b]Below rated capacity rather than above.

The average of the foregoing Department of Commerce percentages, omitting the trucks of 5½ tons and over, is 70.7 per cent. With such overloading of trucks, probably not more than one-third of the tire mileage would be secured which would be gained were loads carried within the carrying capacities of the tires.

Fleet operators should consider the high cost of overloading tires at the time trucks are purchased, and specify tires amply large to carry the expected loads. A good rule to follow is to specify wheels and rims of such size and spacing as will permit oversizing above the size required for anticipated loads. This is an inexpensive factor of safety, and will permit of oversizing should the character of service or size of loads demand oversizing of tire equipment.

Fig. 2 gives the percentage of increase or decrease from normal mileage which may be expected according to the percentage below or above rated carrying capacity of tires. From this chart it is easy to determine whether it would pay to oversize tires.

High speed will also cause heating. The effect of speed on

mileage is shown in Fig. 3. Here again it is a question whether the gain by increased speeds offsets the higher costs.

To get the maximum life out of tires, they must be kept properly inflated. Under-inflation and over-inflation are two great enemies of tire life. Recently a survey was made of a large fleet of trucks in which 40 per cent of the tires were found to be under-inflated and 11 per cent over-inflated. Tire cost in that fleet can be greatly reduced; in fact, if tire inflation were checked each morning before the trucks go out, the company could pay considerably more for tires than it now pays and still realize the same tire cost per mile.

Speed burns up tires, just as it increases fuel and oil consumption and increases repair bills on the chassis. Average speed of all forms of motor vehicles is high; much higher, I imagine, than a great many fleet operators think. According to a survey recently made by the State of Connecticut, the average speed of 10,255 vehicles checked in 145 localities was as follows:

	M.P.H.
Passenger Cars; on city streets	27.9
Passenger Cars; on rural highways	39.7
Trucks; on highways	33.9
Buses; on highways	36.6

It was surprising to me to find that the speed of trucks so closely approximated that of passenger cars.

It is with hesitancy that toe-in is mentioned, because it has long been discussed when tire service is mentioned; but it still remains one of the principal reasons for fast tread wear. Too often the use of a crude home-made measuring-stick results in incorrect measurements of toe-in, when well-constructed substantial measuring devices cost only a few dollars. A single trip of average length may result in wearing off the tread rubber completely if the toe-in is excessive. Frequent checks of toe-in pay for themselves. Some operators make such checks on a mileage basis, others on a time basis. Either method is good, provided the intervals are not too far apart. Both methods should be supplemented by reports of drivers whenever they are in an accident or when they hit anything. Any unusual tread wear should also be observed by visual inspections and corrected.

Under the more common abuses may be listed cuts or abrasion by obstructions on the vehicle. Figs. 4, 5 and 6 illustrate the results of such abuse. This can and should be eliminated at the first indication on the tire. The effect of grabbing brakes, or the result from brakes too quickly applied, is shown in Fig. 6. With the increase in speed of vehicular traffic in general, considerable attention should be devoted to brakes and the manner in which they are applied. Except in emergency cases, it is seldom necessary to bring a vehicle to a stop in the minimum possible distance. Many drivers approach intersections or traffic lights at near maximum speeds and, in case of a necessity to stop, there is no alternative but a severe brake application.

Regarding tire repairs, follow the stitch-in-time theory. Tread cuts let dirt and moisture into the carcass of the tire to ruin it. These may be quickly repaired with the aid of a tread gun; large cuts may necessitate sectional repairs.

Vehicle Repairs

Repairs to motor vehicles are one of the major items upon which we as fleet operators must center our attention. Our aim is to get every mile of service out of each part of a motor vehicle that the manufacturer built into it. We must also devise ways and means of operating and maintaining our

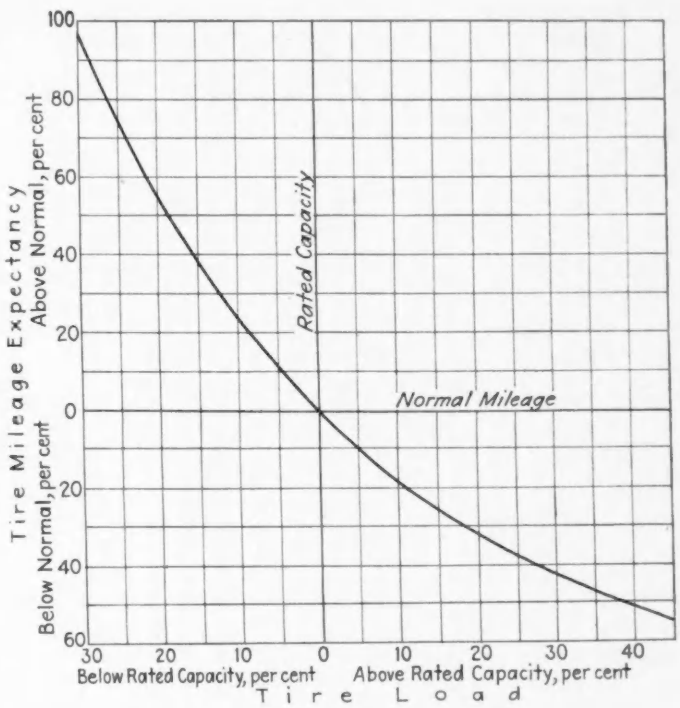


Fig. 2—Percentage of Increase or Decrease from Normal Mileage Which May Be Expected According to the Percentage Below or Above Rated Carrying Capacity of Tires

vehicles so as to keep them out of the repair shop. The most important element in fleet operation is the human one, the driver or operator. The education of those who operate vehicles is the only permanent means through which unnecessary expenses can be reduced; and a great deal of our repair expense today is unnecessary.

I have talked with many operators who tell me that they watch their expenses very carefully and personally supervise and authorize each expenditure. This only means that, after the damage is done, these operators see that the repairs are made promptly and at a reasonable cost; if, however, they had devoted their time to training the driver properly, the necessity for the repairs might never have arisen.

Road and climatic conditions, topography of the country, nature and size of loads carried, all have a direct bearing on repair cost. More miles will be secured out of a vehicle operating on level paved highways than from a similar vehicle operated on rough mountain roads. Taking all factors into consideration, I do not believe that the average fleet operator gets the economical mileage out of his vehicles that he should; in other words, if he keeps the vehicle in service over an extended period, his repair cost is too high.

The driver or operator of any piece of motor equipment is the manager of it. The manner in which he handles the vehicle determines largely just how long it will last and how much it will cost to run. It is difficult for some drivers to appreciate this, and it is up to us as fleet operators to present the picture to them so that they understand it.

Regardless of how well vehicles are driven on the road, how adequately and thoroughly they are lubricated, they will require repairs of some form during their economic life.

During the last five years, there has been a decided swing of the pendulum to preventive maintenance of motor vehicles. We have learned that it will extend vehicle life, reduce unit

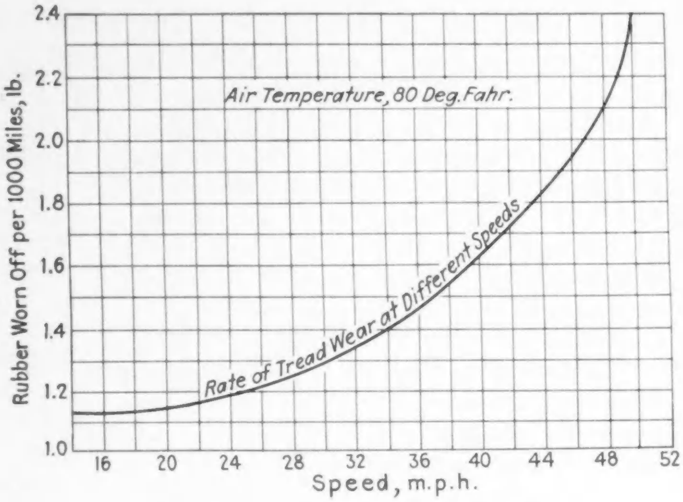


Fig. 3—Effect of Speed on Mileage of Tires

costs, provide a more even maintenance program with greater scheduling ability, and minimize road failures with their resultant costly interruptions of vehicular service. The backbone of preventive maintenance is a scheduled periodic inspection of each vehicle, at which time it is washed, cleaned, greased and all needed repairs and adjustments made that can be done without removing it from normal service. Inspections are best scheduled in off-peak vehicle hours. Repairs found necessary that require removal of the vehicle from service are noted and scheduled to be made at a convenient time. If repairs are to be held to a minimum by preventing the need for repairs and checking small defects before they grow formidable in size, then all motor vehicles must be maintained according to a well-defined standard. It is essential that a definite plan of scheduled maintenance be established; also, that the cooperation of the entire personnel be obtained.

The majority of operators make periodic inspections of vehicles once a month, upon which from 1½ to 4 man-hr. are expended, exclusive of washing time. Some inspect weekly, semi-monthly, every two months or every three months. Of those who inspect on a mileage basis, the majority have selected every 1000 miles as the proper time, while a few do this work only at 2000-mile intervals, supplemented by daily or in-between quick check-overs and greasings.

The daily reporting of defects by drivers has been found valuable in realizing the maximum benefits from preventive maintenance, provided that defects are corrected promptly and are not allowed to accumulate until the vehicle's next periodic inspection date. Periodic inspections can be established equally as well by fleets dependent upon outside maintenance agencies as by those on a self-maintenance basis.

In originally authorizing outside repair shops to perform periodic inspections, the fleet owner's desires as to the work to be done without specific authorization should be very clearly outlined and understood, preferably in writing, and certain general limits in scope of work or costs can easily be established so that the owner's authorized representative is consulted before proceeding with repairs that would be unjustifiable for any reason.

The fleet owner should develop and adopt an inspection routine and report or reports that can be used for all vehicles, whether maintained by himself or by outside agencies for him. This is necessary to assure efficiency control and knowledge of fleet condition as interpreted from inspection reports and charges. Outside maintenance agencies have been found willing to follow such a plan, and its results are very satisfactory. In some small operations certain essential maintenance work is frequently delegated to vehicle operators, such as washing, greasing, tightening up or simple adjustments. In any case, those responsible for vehicular maintenance should establish controls that guarantee correction of defects without delay, else preventive maintenance is only partial and the best results cannot be realized.

Inspection should be made at company or outside garages, preferably the former, where greater interest and responsibility for company-owned equipment and where adequate proper personnel and tool equipment are known to be available. Field or road inspections, made by traveling mechanical inspectors, are less desirable due to obvious limitations and should be used only where equipment cannot economically be maintained any other way. They may be used to advantage at long intervals to check the condition of vehicles maintained exclusively by outside agencies.

After considering various inspection plans and reports, it would appear that the most desirable plan is to perform a major inspection every 90 days (2500 to 3000 miles), with light intermediate inspection every 30 days (1000 miles). For the major inspection a detailed inspection report is necessary; for the minor inspection, a less detailed report, the essential items being checking of distributor points, spark plugs, gasoline strainer, brake adjustments, lights, horn and windshield wiper. Lubrication is also cared for at this time as well as thorough washing and cleaning of the vehicle if time permits. So far as possible, oil changes and lubrication of vehicles should be tied in with the inspection plan. It may be necessary, however, that vehicles be lubricated between inspection periods.

Inspection on a periodic time-basis is most desirable from many angles. It permits the development of a schedule for each interval that can be adhered to without constant attention, enables positive control by the transportation department and, if the work is to be done by company maintenance-forces, permits the scheduling of an even flow of work at each point.

Average mileage developed, types of vehicles used, general service requirements, type of territory operated in, and the like, are the basic factors to consider in establishing the most desirable interval for each fleet. Once the interval has been decided upon, a date, period of the day and place of inspec-

Table 4—Personnel Necessary to Maintain 10 to 100 or More Vehicles, Assuming That Each Man Works 45 Hr. per Week

Personnel	Number of Vehicles					
	10	20	30	40	50	100
Garage Superintendent	—	—	—	—	1	1
Working Foreman	—	—	1	1	1	1
Mechanics	1	1	1	1	2[a]	5[a]
Helpers, Washers and Greasers	—	1	1	2	2[a]	3[a]
Clerks	—	—	—	—	—	1
Stock-Keepers	—	—	—	—	—	1
Combined Clerk and Stock-Keeper	—	—	—	—	1	—

[a] When major overhauling is done, additional help will be required during certain periods of the year.

tion should be established for each vehicle. The majority should be scheduled for night inspection, to obviate removal from normal service. The place of inspection should be set up at the most convenient point with reference to garage location, territory in which used and the loss of the least driving time and mileage to and from inspection points. The ideal arrangement is to inspect at garage points in off-peak vehicle hours, provided the number of vehicles that can be serviced at or from a given point justifies proper maintenance-personnel equipment and materials and supplies thereat.

It has been found desirable to develop a new schedule for each inspection period to allow for the changes in days of the week that particular dates of the month fall on, holidays, changes in the fleet, assignments and vehicles repaired. Contrary to expectations, this can be done quite easily. Department heads should be advised, prior to the beginning of each period, the date, time of day and inspection point that has been set up for each vehicle assigned to them, so that notice to deliver the vehicles to the garage at the proper time is given to the driver of the car or truck.

Our company has found it necessary and desirable to follow this up with an individual reminder notice to the department head, four days in advance of the inspection date of each vehicle. In this case, the notice is turned over to the driver as instructions to comply therewith. It carries a request that the driver note any defects that are apparent to him that might not be apparent to the inspectors, and any other defects that in his judgment should receive attention. The notice is left with the vehicle for the inspector's information. Actual inspections made are checked daily and, if vehicles are not reported as scheduled, department heads are called upon the day after to give the reasons and new dates are set. Some companies have found it advantageous to use an inspection bulletin board upon which the vehicles scheduled for that station for the period are listed as shown in Fig. 7. Inspection reports should be reviewed daily by the transportation manager or a qualified assistant, to note the condition of individual vehicles and any shop work that should be scheduled at a later date.

In any fleet in which vehicles are inspected thoroughly and regularly, the number of defects reported by the operator from day to day should be reduced to a minimum. In other words it is believed that, with a good inspection system, it is possible for vehicles to perform satisfactorily between inspection periods with very few or no repairs necessary between inspections. Any chronic or recurring troubles should be studied and the reasons for those troubles determined and corrected. Only when this is done will true preventive maintenance be employed.

It is obviously impossible to correct for all of the wear, tear and other forms of depreciation that take place in a motor vehicle even when the best of inspection systems and preventive maintenance are employed. It is therefore necessary to overhaul vehicles from time to time; but it is not believed that it is economical to attempt to set up any such overhaul on a predetermined mileage basis. The reason is that the make of vehicle, type of service in which it is employed, character of the driver, climatic and road conditions and other factors have such an important bearing, that, seemingly, it is impossible to predetermine with any fair degree of accuracy just when major repair work will be necessary.

Quite recently, one manufacturer has made available rebuilt engine-assemblies at a very reasonable price to the fleet operator. I believe that this is a big forward step in answering the overhaul problem, and it is hoped that more manufacturers will follow the example. The individual operator cannot overhaul engine assemblies as cheaply as can the manufacturer, as he has not the equipment to do it. Of course, the manufacturer must throw up the same rigid-inspection safeguards around his rebuilt engines that he does around his factory production.

In many companies, repainting of vehicles is performed on a more or less fixed schedule. Where such a schedule is employed, it is customary to do necessary mechanical work on the vehicle before repainting. In such cases, what might be termed major overhauling follows closely more or less with the

Table 5—Tool Equipment Necessary for 10 to 100 or More Vehicles

Tool Equipment	Number of Vehicles					
	10	20	30	40	50	100 or more
Air compressor (small)	1	1	1	1	—	—
Air compressor (large)	—	—	—	—	1	1
Work-bench	1	1	2	3	4	6
Vise	1	1	2	3	4	6
Tire gage (hand type)	1	1	1	1	—	—
Tire gage (wall type)	—	—	—	—	1	1
Creeper	1	1	2	2	3	3
Portable lights	1	2	2	2	3	4
Arbor press (bench)	1	1	1	1	1	1
Arbor press, 40 to 60 ton	—	—	—	—	1	1
Electric drill, ¼ in.	1	1	1	1	1	1
Electric drill, ⅝ in.	—	—	—	—	1	1
Electric-drill stand	1	1	1	1	1	1
High-pressure grease-gun	—	—	—	1	1	1
Hand grease-guns (set)	1	1	1	1	1	1
Grease bucket	1	1	1	1	1	1
Oil-dispensing pumps and tanks	2	2	2	2	2	4
Gasoline pumps and tanks	—	1	1	1	1	1
Jack	1	1	2	2	3	6
Jack (heavy duty)	1	1	1	1	2	2
Inner-tube vulcanizer	1	1	1	1	1	1
Bench grinder	—	1	1	1	—	—
Floor grinder	—	—	—	—	1	1
Chain hoist, 1½ ton	—	1	1	1	1	1
Valve-refacing tools	—	1	1	1	1	1
Valve-reseating tools	—	1	1	1	1	1
Cylinder boring-bar	—	—	—	—	1	1
Cylinder hone	—	1	1	1	1	1
Hi-Lo horses	—	2	2	2	4	6
Blow torch	1	1	1	1	1	1
Soldering iron	1	1	1	1	1	2 Sizes
Reamer sets	—	1	1	1	1	2
Tap and die sets	—	1	1	1	1	2
Hydraulic lift	—	—	1	1	1	2
Wheel pullers (set)	1	1	1	1	1	1
Wheel aligners	—	1	1	1	1	1
Brake-relining machine	—	—	—	1	1	1
Battery charger	1	1	1	1	1	1
Ignition-timing lamp	—	—	1	1	1	1
Electric test-bench	—	—	—	—	—	1
Brake tester	—	—	—	—	—	1
Welding and cutting equipment	—	—	—	—	1	1
Connecting-rod aligner	—	—	—	1	1	1
Body and fender tools	1	1	1	1	1	1
Headlight tester	—	—	—	—	1	1
Micrometers, inside and outside	1	1	1	1	1	1
Hose (washing)	1	1	1	1	—	—
Car washer	—	—	—	—	1	1
Spark-plug tester	1	1	1	1	1	1
Spark-plug cleaner	—	1	1	1	1	1
Lathe	—	—	—	—	—	1
Drill press	—	—	—	—	—	1
Road-mileage tester	—	—	—	—	1	1

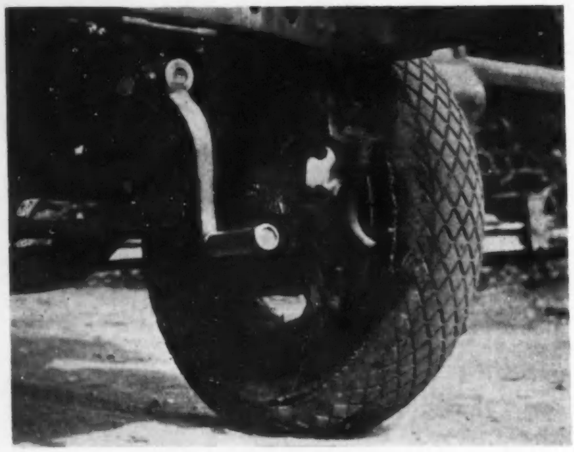


Fig. 4—Tire Cut Caused by Obstruction on the Vehicle

repainting schedule. In other words, if vehicles are repainted every 18 months to 2 years, major repairs are performed at approximately the same intervals.

Systematic planning is essential in performing overhaul work in order that the vehicle may not be held out of service any longer than absolutely necessary. Every repair job involves two costs; that is, the cost of the repair itself and the cost of lost vehicle time. Also, if service to the customer is impaired, this may cost money due to complaints and loss of business.

The magnitude of the automobile repair shop, the personnel and the shop equipment have a direct bearing on the cost of operation of the motor vehicle. Obviously, many considerations affect any plan; hence, in the treatment of this subject only broad and general principles can be dealt with. The number of men required, the tools and equipment which should be provided, are dependent largely upon the number of vehicles to be maintained and the character and age of the fleet.

In regard to personnel, it is felt that where less than ten vehicles are operated in a common territory, the maintenance work, that is, routine inspection, lubrication, adjustment and minor repairs, should be performed by public garages or outside agencies. Likewise, major repairs and overhauling, painting and the like should be done in outside shops. Table 4 sets forth the personnel believed necessary to maintain a fleet of from 10 to 100 vehicles. It is presumed that the employees shown will perform all work except major overhauling and painting, except where notations are made to the contrary. The number of hours per week which the men work enters into the question as to how many are necessary; therefore, I have presumed that each man works 45 hr. per week.

Where vehicles are properly maintained from day to day, complete overhauling or rebuilding is unnecessary. Major repairs to certain units will in time be required, but it is felt that it no longer is necessary to completely "tear down" a vehicle and then rebuild it, as was the practice a few years ago.

Proper tool equipment is essential to assure that good and efficient work is done. The tool equipment believed necessary to maintain vehicles numbering 10 to 100 and more is shown in Table 5. The list includes all of the major items of tools and equipment which are believed necessary in various sizes of automotive shops. Small hand-tools are not listed, because it is customary for each mechanic to furnish his own tools.

Salvaging of repair parts is necessary to obtain economies and to secure the life out of parts which the manufacturer built into them. Generally speaking, mechanics like to install new parts rather than to reclaim old ones. It is only human nature for them to like to work with new material. In the interests of economy it is essential that proper safeguards be set up to be certain that old parts will be re-used if still serviceable and that, in performing repairs, good judgment be exercised on the necessity for replacing a part.

A discussion of repair expense would be incomplete without again mentioning the importance of governors and air cleaners in fleet operation. Governors limiting the speed of vehicles to reasonable limits will reduce the necessity for repairs.

It is my belief that air cleaners are essential, especially where vehicles are operated in dusty country. Dirt in the fuel mixture is one of the primary causes of premature cylinder wear. Some time ago I had this forcefully called to

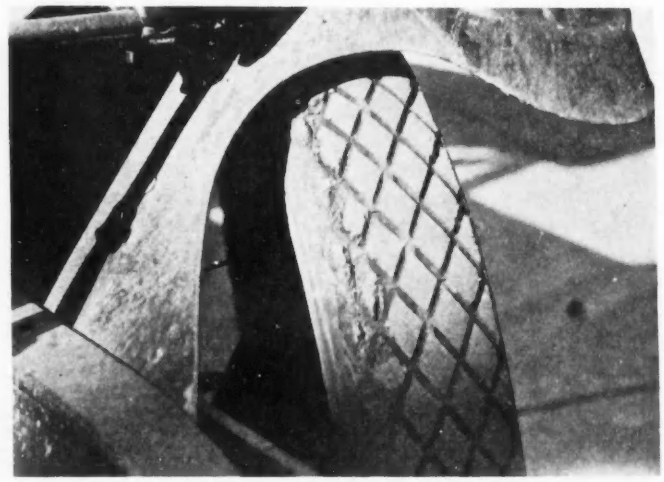


Fig. 5—Tire Abrasion Caused by Obstruction on the Vehicle

my attention. We had a 2-ton truck working in Oklahoma, and it did not have an air cleaner. The roads were dusty and when the truck had traveled approximately 7000 miles it was reported as having no power. Examination disclosed the necessity for regrinding the block and fitting new piston rings and piston pins. The engine was then equipped with a good oil-bath-type air-cleaner. The vehicle has since traveled 22,000 miles and the engine is still in good condition.

Those who operate their own repair shops know that the question of how much stock to carry is an important one. Control of this item is essential to hold the amount of the inventory to a minimum and to prevent loss through obsolescence. I do not favor carrying enough stock so that any job can be performed without going out to buy material; on the other hand, I believe that fast moving parts should be kept on hand—a reasonable stock—so that work in the shop will not be interrupted with consequent loss of mechanics' and vehicle time.

The cost of repainting motor vehicles in any fleet depends primarily upon the age of the fleet, how much "value of appearance" is valued at, or, in other words, how often the vehicles are repainted, the type of painting scheme and the nature of the materials employed. During hard times

many companies neglect to repaint their vehicles as often as they should. No company can afford to neglect the appearance of its vehicles. Often, the vehicle and the driver are the only physical tie that a business house has with its customers. The appearance of the vehicle does much to mould the public's opinion of the concern that owns it. Aside from these considerations, good paint is essential to preserve the surface of the vehicle against the elements; further, the psychological effect on the driver or operator is marked. Invariably, a driver will treat a well-painted vehicle more carefully than one whose appearance is bad.

About three years ago developments in the field of synthetic resins of the phenol-aldehyde type permitted the quickening of drying time of enamel, apparently without sacrifice in durability or other properties; likewise, the drying time of primer sealer was shortened. This made it possible to apply two coats of primer surfacer in the same day, as it dried in 4 hr. ready to recoat; this being followed with one coat of enamel the second day, which dried in 24 hr. The time necessary for repainting was thereby reduced about 1 day, as compared with systems formerly used.

The newest entry in the field of automotive finishes is a synthetic enamel-finish of an entirely different type, one having as the varnish base a straight synthetic resin of the glycerol phthalate type, commonly known as glyptol. The complete finish consists of primer surfacer, enamel, and possibly clear finishing varnish. The primer is frequently made on an oil or varnish base, while the other materials are synthetic. As a general rule, the use of clear finishing varnish is not recommended except for penciling decorations.

Synthetic finishes incorporate most of the properties desired for automotive work. They are suitable for use over wood as well as metal. All of the synthetic finishes are designed for spraying and the products of a few manufacturers may also be brushed. Broadly speaking, they do not brush as well as oil enamel but spray better. The undercoats dry approximately the same as the undercoats in the quick-drying oil-enamel system, but the enamel coat dries more rapidly. Two coats of the enamel may be applied in a day and it is ready for masking the following day, or sooner. Synthetic finishes have considerably less body per coat than varnish or oil enamel and on the average they have less initial gloss. Possessing excellent general durability, they are outstanding in freedom from dulling and color fading. The choice between an oil or varnish enamel and a synthetic enamel is close and is governed largely by the circumstances connected with the particular fleet of equipment, such as the type of vehicles, number of colors and the particular colors, appearance required, importance of speed and shop conditions. Through the adoption of the best system for any given work, painting cost may be reduced. The newer types of finishes offered purport well to give us better appearing vehicles at lower cost.

Fig. 6—Effect of Grabbing Brakes on Tires

Accidents

Traffic accidents have long been accepted rather apathetically by industry and by the general public as being the result of causes beyond human control. For some years our companies have been maintaining a high standard of maintenance on our transportation equipment. Brakes, lights, horns and steering gears, have been examined carefully at each inspection period with accident prevention in mind, the greatest care being taken so that mechanical failures of the vehicles would not occur and possibly be responsible for accidents. Rear-view mirrors, reflector lights, stop signals and some direction indicators, have been installed on our vehicles in our efforts to prevent accidents.

Up to 1929, accidents failed to decrease in most of our companies to any material degree. Our accident records as a whole were not bad—some could even be called satisfactory—yet there was room for much improvement. After a study of our accidents, it was plainly shown that mechanical defects in the vehicles played a minor part. We found, as the Travelers Insurance Co. found, that most accidents occurred when all mechanical conditions, time, road and weather conditions, were in the drivers' favor. The real causes for the accidents were drivers' inattention, driving too fast, failure to observe the rules of the road and neglect of the rules of common courtesy.

In one of our companies operating 411 motor vehicles which 980 different employees drove in the course of their work, the accident records were studied from Jan. 1, 1927, and it was found that about 18 per cent of the drivers had more than 60 per cent of the accidents. A code entitled Safe Driving Practices was published and distributed in 1931 and subsequently it was decided to subject to vision and hearing tests all employees who drove vehicles. Twenty were found with defective vision and correction was made by fitting them with eyeglasses.

Permit cards were then issued to all employees having occasion to drive the company's vehicles. To those having had an accident within the last year, white cards were issued; to those having operated vehicles more than one year without an accident, red or honor cards were issued; those having two years to their credit without an accident received blue honor cards. All employees prize their honor cards and guard against accidents because, if they have one and if the traffic-accident committee places blame for an accident, the honor card is taken up and a white card issued unless more rigid discipline is prescribed.

To show what has been accomplished in this company, let me cite the following. In 1931, 417 vehicles were operated 4,472,976 miles with 105 accidents, a frequency rate of 2.35 accidents per 100,000 miles. In 1932, there were 388 vehicles which operated 4,111,673 miles with 46 accidents, a frequency rate of 1.12 accidents per 100,000 miles. The public utilities rate during this period was 2.51. During the first five months of 1933, there were 387 vehicles which operated 1,621,082 miles with 17 accidents, a frequency rate of 1.05 accidents per 100,000 miles. The public utilities average for the same period is 2.08. This experience gained in one of our companies is a good indication of what can be accomplished if accident-prevention work is gone into seriously. Transportation costs have been reduced through eliminating repairs made necessary to our vehicles by accidents.

Garage Expenses

In our accounting procedure the cost of labor used in washing, gassing, greasing and oiling motor vehicles, and also the labor involved in delivering, picking up and parking vehicles in the garage, is charged to this account. We also charge the cost of miscellaneous supplies, such as the following, to this account largely because it simplifies accounting.

Greases	Brooms
Lubricants, except motor oil	Floor Brushes
Penetrating Oil	Shovels
Battery Water	Soap
Rags and Waste	Toilet Paper
Sponges	Towels
Chamois	Mops
Nickel Polish	Mop Handles
Brass Polish	Ice
Body Polish	Drinking Water
Kerosene	Fire - Extinguisher Maintenance
Rubber Boots	Electricity for Lighting
Rubber Aprons	Electric-Light Bulbs
Graphite	Cost of Water
Water Hose	

Upkeep of electrical charging-equipment, gasoline pumps and tanks, motor-oil pumps and tanks, grease-dispensing equipment, air compressors and the like, is also charged to garage expenses. Obviously, the cost of garage expense can only be reduced by decreasing labor and material costs.

Washing vehicles and cleaning engines constitute an important part of our maintenance work. Vehicles must be kept clean, otherwise our maintenance is not good. We have found that power washing-devices such as increased water pressure obtained by power-driven pumps, or the combination of water and air under pressure, speed up very materially the cleaning of accumulated mud and dirt from the chassis. For washing buses we have found that running them through a spray or shower simplifies and speeds up the washing operations. Generally speaking, I believe that we have progressed a great deal further in washing buses economically than we have in washing passenger cars and trucks. This may be because the sizes of the buses are more nearly uniform. I feel, however, that the spray or shower-bath type of washing equipment, when properly developed for passenger cars and trucks, combined with pressure washing of the chassis, presents vast possibilities of reducing washing time.

Engine cleaning is being accomplished by various means, depending upon the size and nature of our garages. Steam, hot water and air pressure, and kerosene and air pressure, are the three means employed. The two systems first mentioned are preferable unless the wash rack has adequate ventilation, in which case the use of kerosene and air pressure is quite satisfactory.

The cost of miscellaneous supplies charged to garage expense can be reduced through elimination of waste and unnecessary use of materials. This resolves into a problem of supervision. Likewise, the unnecessary use of light and water can be reduced. The equipment needed for economical and adequate lubrication has already been outlined.

Fixed Charges

Rent, insurance, licenses and taxes, depreciation reserve, interest and general or administrative expense are usually termed "fixed charges." Depreciation reserve is the only one of these items discussed in this paper.

The purpose of a depreciation reserve is to build up out of earnings a fund ample to make replacement of vehicles when they are worn out or are no longer economical to operate. Various methods are employed in setting up this reserve. Some depreciate their vehicles on a time basis, others on a mileage basis and still others on a combination of time and mileage. I prefer the last scheme inasmuch as I feel that it takes cognizance of obsolescence, also the deterioration that takes place in vehicles with age under low usage conditions.

The amount of the reserve to be set up is dependent upon the operator's maintenance procedure and his policy of making replacements. I have seen some formulas offered to govern arithmetically or otherwise the proper time for replacements to be made. I have yet to find one that can be generally applied. There are too many variables and qualifying factors that must be given recognition. It is my belief that each vehicle must be considered separately to account for differences in usage, wear and tear.

Aside from cost of operation, which is a basic determinant, we must consider obsolescence. This can be due to the age of the vehicle, changed work methods or requirements, advanced chassis and body design, greater economy of operation of newer models, increased safe speeds desirable or necessary, traffic requirements, continued ability to maintain good appearance and, finally, and probably most important, availability of cash with which to make replacements.

Purchase of New Vehicles

The fleet owner, in making his purchases of passenger cars, must accept the current offerings of the manufacturers, and he does not have the same opportunity of injecting his ideas into the design of these vehicles that he has in the purchase of trucks and buses. In other words, he must select the particular car that appears best suited for his requirements and fit it into his operation the best he can.

I recognize that there is an excellent reason why this is so; namely, that the manufacturer is building cars to suit the masses and not for any particular group or industry. I further realize that the low cost of cars today is due to quantity production and that our vehicles would cost a great deal more were it not for quantity buying on the part of the public.

The manufacturers, during recent years, have been called upon to exercise the greatest ingenuity in creating a buying demand on the part of the public. The skill and promptness with which they could bring out new models that, through their performance, styling and appearance, outmoded the old models, determined largely their success. Standardization in passenger cars on the part of the fleet owner, under the

foregoing conditions, means standardization in name only, as the interchangeability of parts between models is slight. This possibly is one of the penalties that we must pay for progress in the art.

Manufacturers would help the fleet owner greatly if greater interchangeability of parts were offered.

We want as simple a vehicle as possible, free from gadgets and automatic devices that invariably increase maintenance expense. Within the last year, certain manufacturers have offered "standard" models on which certain devices, chromium plating, finer upholstery and hardware, have been eliminated that were features in their de-luxe line. This is a step in the right direction so far as the fleet user is concerned.

I would like to see the manufacturers of the small popular-priced cars go still further and develop "standard" models of 108 or 110-in. wheelbase with smaller and more economical four or six-cylinder engines of approximately 140 to 150-cu. in. displacement developing a maximum of 40 hp. The coupe or sedan should weigh not over 2000 lb. and preferably less, and gear ratios and maximum engine speed should be such as would limit maximum road speed to 55 m.p.h. Rapid acceleration or pick-up is unnecessary, and only moderate performance is required. The car should have a standard tread, conservative low-air pressure tires, a body designed for commercial work that will last as long as the chassis, serviceable upholstery, durable seat cushions and shatter-proof glass.

Shackle bolts, king pins and universal joints, should be so designed and built of such materials as to give long life without renewals. More attention should be paid to adequate lubrication of all chassis parts, and the means of lubricating these parts should be simplified. A good air cleaner of ample size should be standard equipment. Every part of the car should be designed with ease of maintenance in mind.

Some may say that such a vehicle as I have visualized would not be desired by the public. Personally, I believe that higher fuel costs and higher commodity prices are going to popularize the small economical car a lot sooner than some may believe. I believe further that a car with characteristics that I have outlined could be "dolled up" and "gadgeted" and offered as a de-luxe model, and that such a car would be welcomed by the public.

Most of us in recent years have seen what can be done with light-weight pneumatic-tired trucks. We know that in many applications they have successfully supplanted the heavy-duty solid-tired vehicle. We have seen what can be accomplished with tractors and semi-trailers, four-wheel trailers and six-wheel trucks. Due to retrenchment programs which have been in effect during the last three years in very nearly all lines of business, we have not been enabled to replace some of the old vehicles that we have with those of the newer type.

Buses, too, have been decreased in weight, due to employment of better and lighter materials and, further, due to the realization of bus operators that smaller-capacity buses are more economical to operate and better fitted their average seating demands.

There comes a time in the life of every type of machinery or equipment when no amount of finesse of detail will overbalance the basic advantages offered by equipment of more sound design. The passenger cars, trucks and buses that are now available and those that are to come will be the new tools of the fleet operator and these, combined with intelligent operation, will bring transportation costs to lower levels than we have ever previously attained.

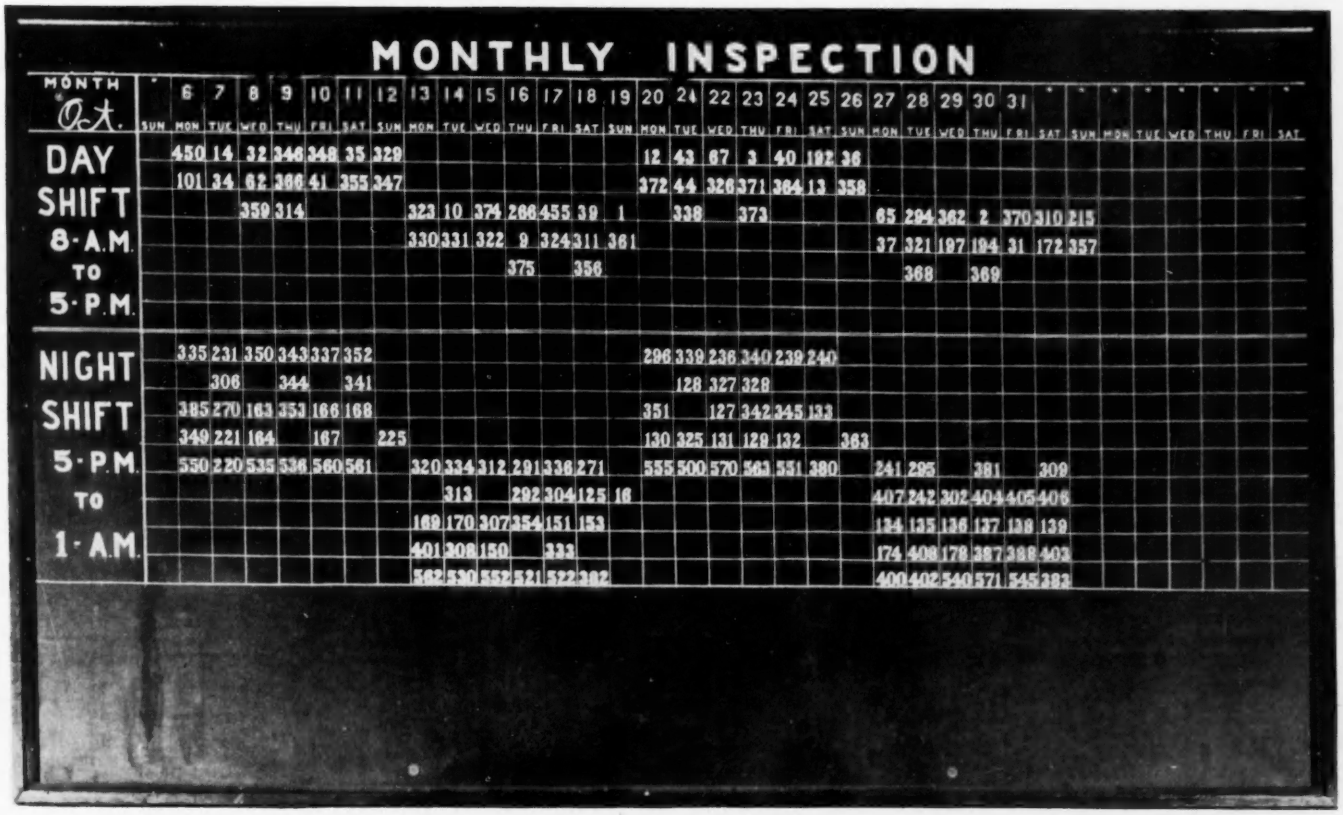


Fig. 7—Inspection Bulletin-Board Upon Which the Vehicles Scheduled for That Station for the Inspection Period Are Listed

Varied Opinion Marks Discussion of McKee-Bitner-McKee Paper

ON the following pages appears discussion of the paper, "Apparatus for Determining Load-Carrying Capacity of Extreme-Pressure Lubricants" by S. A. McKee, F. G. Bitner, and T. R. McKee, which was presented at the International Automotive Engineering Congress, Chicago, September, 1933, and published in the December, 1933, issue of the S.A.E. JOURNAL, pages 402-408.

The paper dealt with the work done at the U. S. Bureau of Standards in development of laboratory apparatus and test methods for determining those characteristics of extreme-pressure lubricants which have to do with load-carrying capacity. The work on this problem was done in cooperation with the S.A.E. Lubricants Research Subcommittee.

Compliments Apparatus and Results of Tests

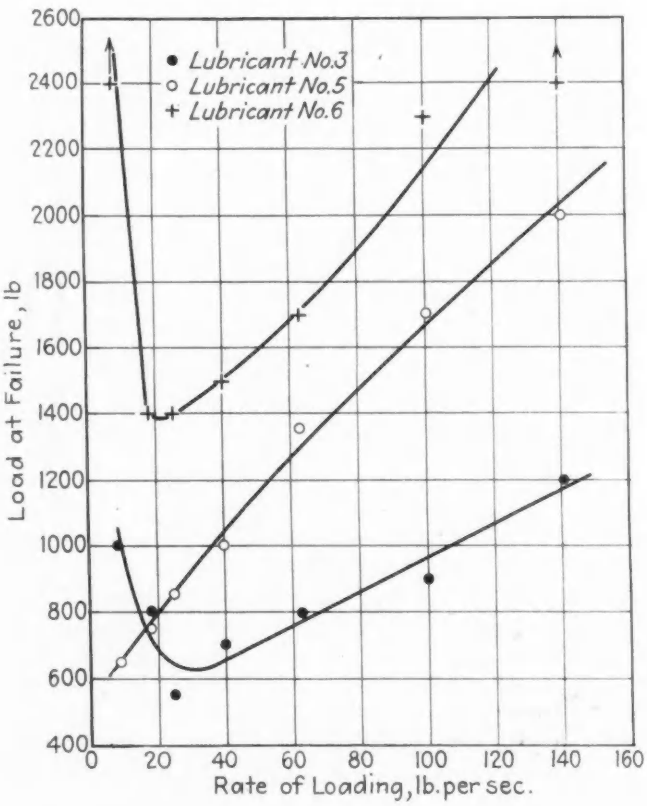
—**H. C. Mougey**
General Motors Corp.

THE authors of the paper, "Apparatus for Determining Load-Carrying Capacity of Extreme-Pressure Lubricants," are to be congratulated on the progress which they have made.

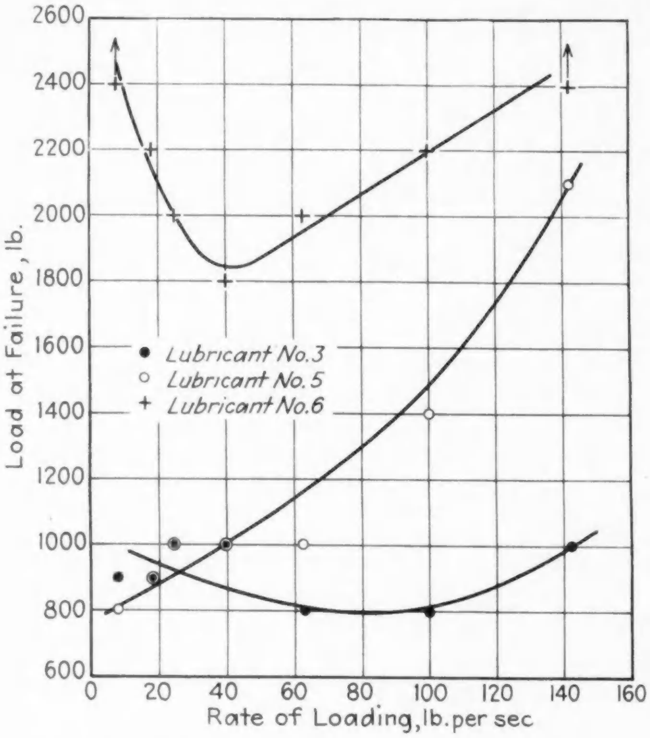
The machine which they have developed makes it possible to approach much more closely the actual set of conditions that occur in service with hypoid and heavily loaded spiral bevel gears than do other machines with which we are familiar.

The varying results which the authors have obtained under different conditions show that the one most important factor is the temperature in the surfaces subject to possible scoring, and the rate of chemical action and the chemical film formed between the bearing surfaces as a result of this temperature. Of course, the temperatures in the surfaces where scoring is likely to occur are very much greater than the temperatures measured in the mass of oil.

Although the machine which the authors have developed differs from ours in many respects, it appears that they are able to make a delicate control of the temperature and rate of change of temperature in the surfaces where scoring might occur by making in the operation of the machine, changes which do not have to be controlled with a high degree of accuracy. For example, the set of conditions shown with an 80 lb. per sec. rate of loading in the chart illustrated below with a bath temperature of 28 deg. cent. (82.4 deg. fahr.) will grade the lubricants very much in the same order as an 80 lb. or 100 lb. per sec. rate of loading with 100 deg. cent. bath as shown in the chart illustrated on the opposite page. In other words, it appears that this relatively large variation in operating conditions is able to produce in the bearing sur-



The above chart, referred to in Mr. Mougey's discussion, appeared as Fig. 6 in the McKee, Bitner and McKee paper, published in the December issue of the S.A.E. JOURNAL, page 405.



The above chart, referred to in Mr. Mougey's discussion, appeared as Fig. 7 in the McKee, Bitner and McKee paper, published in the December issue of the S.A.E. Journal, page 406.

faces a very delicate control of temperature and rate of chemical action and that the results obtained in the two cases are approximately the same.

From the above facts it appears that the commercial variations between different machines and different unavoidable variations in operations should not interfere with obtaining comparable results in different laboratories. If this can be done and the lubricants graded in terms of their performance in service, then the first part of the program of the committee will have been accomplished. It is my feeling that checks to establish these points should be made at once with several laboratories cooperating.

Limitations and Values of Test Data Discussed

—Ernest Wooler
Timken Roller Bearing Co.

THE machine developed by the U. S. Bureau of Standards seems to be entirely a research apparatus at it appears to be too complicated both in the driving mechanism and the method of loading to be suitable for a commercial laboratory testing machine. The device appears to fill the requirements for research purposes for the determination of load-carrying capacity of lubricants, but evidently does not have a sufficient range to break down commercial lubricants at present on the market and therefore does not take care of development of increased load-carrying capacity of future lubricants.

The results obtained are not conclusive as a limited number of tests have been conducted, but from the results obtained to date the machine gives great promise of determining fairly accurately the load-carrying capacity of lubricants under various conditions of use.

The lubricants which have been tested and reported on are declared to be rated in the order found in service. It has been our experience that it is very difficult to determine the relative merits in service of various lubricants on the market, and it would be interesting to know just how the determination of service results were arrived at. Our experience to date is that no definite agreement exists between users or manufacturers as to the best lubricants in service for load-carrying capacity. The curves shown with the paper indicate that at both high temperatures and high loads the lubricants rated themselves in the same order. It would therefore seem that a simplified procedure for commercial testing could be adopted at some definite speed if this is found true for all lubricants.

The application of variable loads during the test does not seem to be warranted from the results obtained and this might be simplified by checking at one or two definite constant loads.

The results obtained check fairly closely to those obtained by the Timken Roller Bearing Co. in order of merit, except that we have found that some chlorinated products are better than any lead soap on the market. It should be borne in mind that although a particular lubricant has a better load-carrying capacity than another, lack of stability plays a very important part in determining the final merits of a lubricant as it is much better to have a stable product even though the load-carrying capacity may be lower than some other lubricant but being unstable either in service or in storage.

Another factor which should be taken into account in determining the relative merits will be the abrasiveness of the lubricant, so that a lubricant should not be chosen solely on its load-carrying capacity. From our study of the paper we are inclined to feel that information on abrasiveness, stability, etc., could be had by the present machine. While it is observed that the first problem of the Bureau was to develop a machine for the determination of load-carrying capacity, the abrasiveness of a lubricant is also extremely important and by the machine just developed this quality of a lubricant could also be determined by weighing the test specimens for loss of weight which would be an indication of its abrasiveness.

The authors state that high temperatures seem to assist the formation of protective coating which increases the load-carrying capacity. In our experience this is not always the case, as we have noted just the opposite in a number of lubricants we have tested.

They also mention that it may be necessary to choose a somewhat different method of loading than is employed in order to rate lubricants properly. Today, sulphur, chlorine and lead soap seem to be the primary substances used to give load-carrying capacity and since each of these substances act different chemically, naturally we feel that one set of testing conditions would not show up the properties in the same order. It is naturally assumed that under different operating conditions lubricants containing these different substances would show up differently.

There are at present on the market a large number of fairly satisfactory extreme-pressure lubricants and these have been developed by the use of machines that have been used during the last three years. So we must admit that results can be interpreted from these machines, because satisfactory extreme-pressure lubricants have been developed from data

obtained on them. We are therefore inclined to feel that this machine at present is not far enough ahead of the present machines to replace them at this time, and therefore more development work over a wider range of lubricants should be conducted before asking the makers and consumers of lubricants to replace their present equipment.

We wish to call attention to the fact that there are already on the market a large number of extreme-pressure greases and that any new apparatus developed should be designed so that it will test this type of lubricant as well as fluid lubricants.

Additional Data on Wear Presented Graphically

—B. E. Sibley
Continental Oil Co.

IN discussing test results, the authors conclude one paragraph with the statement, "One possible reason for this difference is that in this machine the constantly changing points of contact provide a means of dissipation of heat."[1] This may seem to be contradictory to the statement in the next paragraph: "In the first place, high temperature seems to assist the formation of a protective coating which increases the load-carrying capacity." The first quotation infers that the apparently higher load-carrying capacity, as noted by test results of this machine, may be due to heat dissipation, thereby resulting in lower working temperatures, whereas it is later stated high temperature seems to promote increased load-carrying capacity.

Consideration should be given to the loosely held (chemically) extreme-pressure material that may be liberated by the effect of high temperatures. These liberated particles apparently have a corrosive effect on the working faces of the metals, resulting in a high extreme-pressure reading. Further investigation may reveal that a high extreme-pressure rating may be secured through the corrosive action of loosely held materials which are liberated at the higher temperatures, while other lubricants of extreme-pressure characteristics actually have higher film strength and are not dependent upon the corrosive feature in securing high extreme-pressure readings.

Obviously wear is one of the most important features in connection with extreme-pressure lubricants, as extreme-pressure characteristics are of little value where the rate of wear is extremely high.

Somewhat over a year ago we developed an extreme-pressure testing machine very similar to the apparatus discussed by the authors of this paper. That machine was used in securing wear data. The friction rings were weighed before use and at different periods during testing. The lubricant used was an extreme-pressure type. Lubricant No. 1 contained an oil of approximately 100 viscosity, and lubricant No. 2 contained an oil of 190 viscosity at 210 deg. Fahr. The same extreme-pressure material and amounts were used in both No. 1 and No. 2 lubricants.

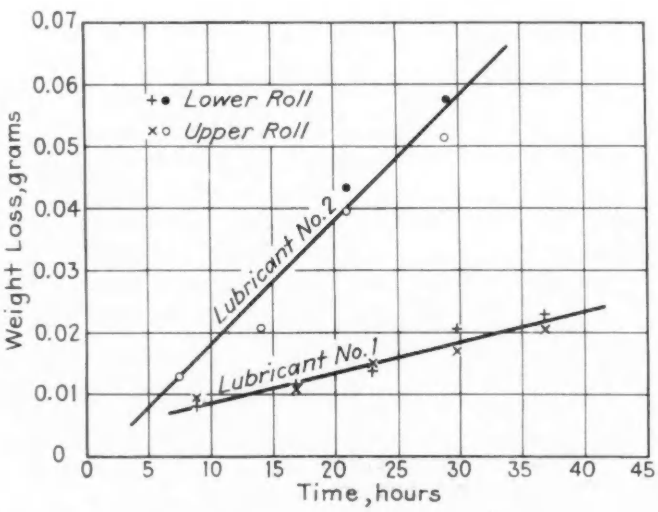
The wear was determined by the weight loss in a given length of time. The results are submitted in graphical form in the accompanying chart. A very appreciable difference in the rate of wear is shown; a much lower rate occurred with the less viscous product. One may reasonably assume that the more favorable result with the less viscous product is due to better distribution to the rubbing surfaces, which assures a better lubricated condition.

Operating equipment is subjected to shock loads and distortion or misalignment, which result in terrifically high pressures, somewhat localized because of alignment and load conditions. In discussing that condition, a representative of one of the largest users of hypoid gears commented to the effect that they could not depend upon results of laboratory tests involving extreme-pressure lubricants, as it was their opinion much greater stresses were involved.

Sulphur was used in some of the nine lubricants reported upon by the authors of this paper. Our work with a sulphur constituent reveals that the materials worked with were somewhat sensitive as to the amount of sulphur that could be used with satisfactory results. A plotted curve of the sulphur content peaks rather sharply. Using more than the proper amount lowers the extreme-pressure characteristics; in fact, it lowers the extreme pressure below what it would be without the addition of sulphur. The ratio of the sulphur used holds quite steadily throughout various percentages of the amount of extreme-pressure stock added to the lubricant.

In the practical use of extreme-pressure lubricants, a wide range of temperatures is encountered—from near that of the atmosphere to appreciably high temperatures. The lubricant in service is confronted with changeable and high temperature conditions, and it is interesting to know the resulting effect of such conditions upon the extreme-pressure characteristics. The result of our work in general is in agreement with that of others, as it reveals very decided changes in the extreme-pressure feature occurring when confronted with these heat conditions over a reasonable length of time. Occasionally the lubricant that shows the highest extreme-pressure characteristics before use or before being subjected to working temperature conditions will take a much lower rating as compared with another product showing lower extreme-pressure characteristics before heating. Subjecting extreme-pressure lubricants to working heats for a reasonable length of time will frequently rate them in a different order than before heating.

The apparatus discussed by the authors appeals to us as being the most satisfactory, as the toothless gear feature practically eliminates objections raised in connection with other testing equipment of that type.



Weight Loss with Time in Double Roll Machine at a Load of 300 Lb.

[1] See S.A.E. JOURNAL, December, 1933, p. 407.